

SEPTEMBER 1961

# modern castings

the technology-for-profit magazine



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Market Opportunities  
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**ALUMINUM**  
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## WATER-COOLED CUPOLA OPERATION — benefited by hot blast . . .

**MAX.  
QUALITY**

**DUCTILE IRON**

**MIN.  
COST**

MODERN  
HF 60 WC

- **CHARGING . . .**
- **MELTING . . .**
- **POURING!**

For the ALL-NEW Briggs & Stratton Foundry in Milwaukee the choice favored ALL-MODERN equipment for charging . . . melting and pouring — 60" water-cooled cupola melting; 750° F., externally-fired, hot blast; 42" x 42" small-cone bucket for charging; and MODERN ladles for holding, inoculating and conveyor line, electric pouring. Melting progresses against the water-cooled, steel shell. Slag composition is completely independent of lining effects.

Metallurgical control is assured. Labor is minimized by the MODERN skip charger which operates complete with small-cone, orange-peel bucket; automatic weighing; coke and flux bins:

Served by a 7½-ton magnet crane. Whenever new and unusually tough problems arise in your selection of equipment, which is engineered metallurgically as well as mechanically to your requirements, we'd like to think with you in your early-stage planning. May we send catalogs?

Skip charger with 42" x 42" small-cone bucket. 7½ ton, 50 ft. span magnet crane services the bins.

Overhead traverse is synchronized with conveyor for electrified pouring.



**MODERN EQUIPMENT CO., Dept. MC-9**  
**Port Washington, Wisconsin**

Circle No. 122, Pages 141-142

# modern castings

metalcasting "technology-for-profit"

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**CONTROL  
EFFICIENCY  
ECONOMY**  
in your molding operation?

If not, analyze below the most persistent molding problems and check the recommended ADM product under the "solution" column. Complete the coupon, tear off and mail to ADM. We will send you technical information on the application and performance of the products in which you have expressed an interest.

**IF YOU HAVE A MOLDING PROBLEM:**

- ☐ Do you have to clean patterns often? .....
- ☐ Do you get hard surfaces in castings due to sulphur pickup? .....
- ☐ Poor shakeout? .....
- ☐ Are you getting clean pool? .....
- ☐ Getting cuts, washes, erosion and inclusions? .....
- ☐ Getting burn-in or rough surfaces? .....
- ☐ Any rat-tails, buckles, scabs or hot tears? .....
- ☐ Is scrap rate high due to weak sand? .....
- ☐ Soft spots from poor flowability in high-bond sand? .....

**THERE'S AN ADM SOLUTION:**

- ☐ ARCHER PARTINGS
- ☐ CROWN HILL SEACOAL
- ☐ LIN-O-CEL
- ☐ CROWN HILL SEACOAL
- ☐ GREEN BOND BENTONITE
- ☐ VELVA WASHES
- ☐ LIN-O-CEL
- ☐ GREEN BOND BENTONITE
- ☐ LIN-O-CEL

OTHER PROBLEMS: \_\_\_\_\_

NAME \_\_\_\_\_

TITLE \_\_\_\_\_

FOUNDRY \_\_\_\_\_

ADDRESS \_\_\_\_\_

CITY \_\_\_\_\_

ZONE \_\_\_\_\_ STATE \_\_\_\_\_



**Archer-Daniels-Midland company**

**FEDERAL FOUNDRY SUPPLY DIVISION**

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## modern castings

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## Let's look at...

### METALCASTING BUYING POWER

**M**ODERN CASTINGS continues to make news! This time it's about you, the value you have as a customer to our advertisers.

Just completed is a Market Profile study of our metalcasting readers. It tells who you are, what you are like, what you buy, how you participate in purchasing decisions.

We know that you are dynamic, stable, experienced and alert! Almost 38 per cent of you have gained your present job titles within the last four years. More than 50 per cent have been in your present jobs more than 7½ years; and 50 per cent have been in metalcasting for more than 21 years.

More than 87 per cent say that you find trade magazines and journals, such as MODERN CASTINGS, helpful to you in the performance of your job. This is the highest ranking of any source mentioned by far!

Significantly, most of you are in management . . . but you also perform technical duties and make both management and technical decisions.



H. E. Green

Per Cent	Primary Job Function and Title
24.2	Corporate Management
7.8	Technical Management
34.8	Production Management
7.2	Production Engineering
3.4	Process Control
4.1	Research and Development
3.7	Sales and Advertising
2.3	Consulting

But you perform many functions besides what is indicated by your job title:

69.3 percent have assigned main management functions, including procurement.

60.7 per cent are concerned with production management.

Most significant is the participation in purchasing decisions for equipment and supplies.

85.4 per cent participate in company purchase decisions. (93.7 per cent of those in management and procurement!)

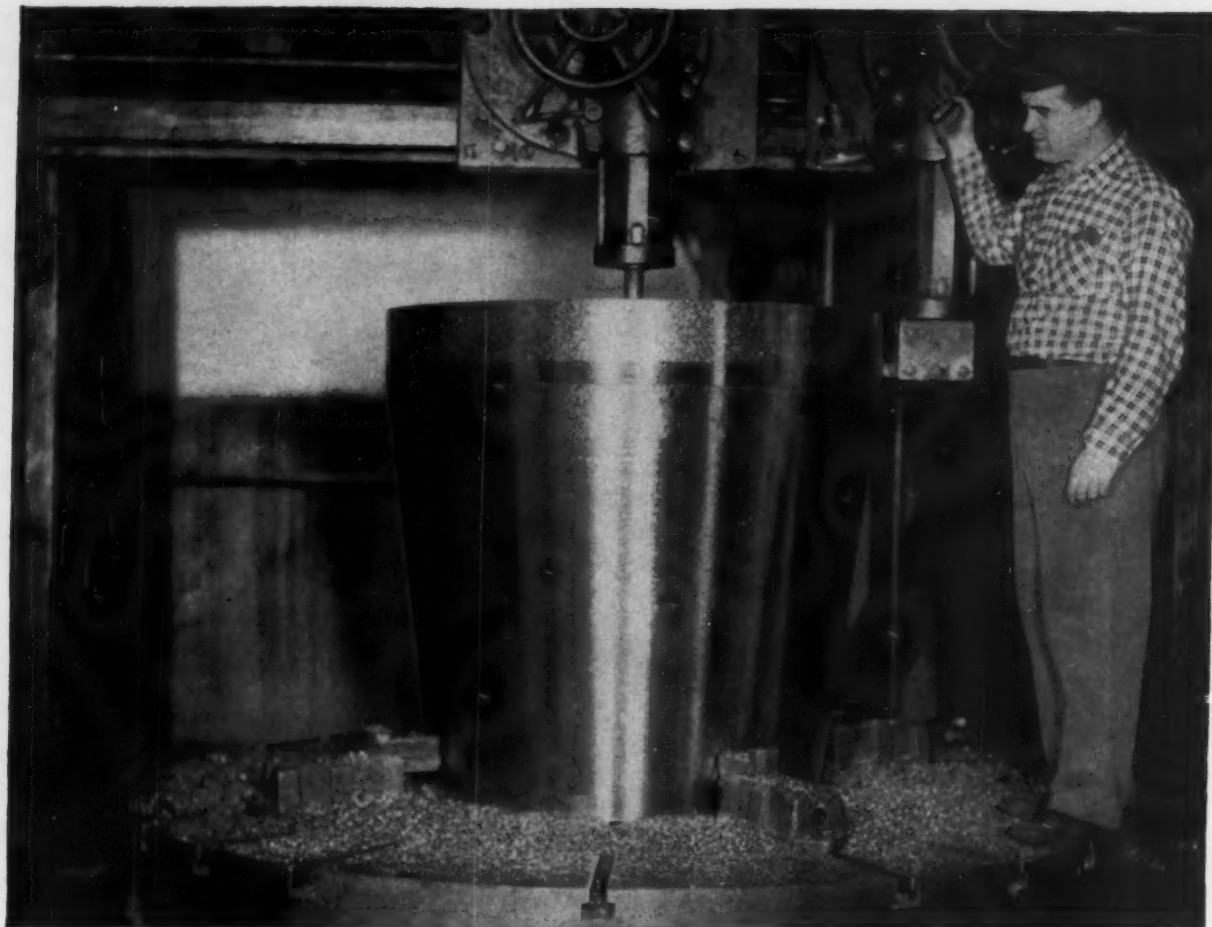
77.2 per cent participate in determining product specifications.

61.9 per cent participate in determining the brand or the manufacturer.

What does this mean? It reveals that you are a top quality audience for advertisers.

Be sure to read the Market Opportunities report for this issue. It's about sales opportunities for you in the automotive field. Also, beginning on page 11 is a new department based on interests important to you . . . decisions and activities in Washington that affect you and your job. It's by W. R. Fingal, our Washington Editor—Capitol Hill veteran and also the son of a metalcaster! It's called "Metalcasting and Washington!"

*Harold E. Green*



## Cone made of Ni-Vee\* bronze to last 5 times longer in acid river water

The filter cone you see above is being readied for work in corrosive Monongahela River water.

That's why it's made of Ni-Vee bronze.

Expected life is at least five times longer than its predecessor, a grey iron cone now badly eaten away. Installed in a 12" automatic self-cleaning strainer, the Ni-Vee bronze cone will give long-lasting support to filter elements that remove solids from water used for blast furnace cooling.

Another important consideration in making this cone was machinability — all outer surfaces were drilled to receive filtering elements.

Ni-Vee bronze easily met this need.

### Versatile Ni-Vee bronze

Ni-Vee bronze does a multitude of industrial jobs. Five basic bronze compositions are available — Ni-Vee A, B, C, D, and E. They're modifiable to meet all industrial needs for brass and bronze constructional, pressure or bearing castings.


All the Ni-Vee bronzes deliver excellent "as cast" strength, improvable with heat treatment. (For example, Ni-Vee A bronze yield strength can be increased from 22,000 psi as cast, to 55,000 psi!) In addition, they supply easy castability, low shrinkage, pressure tightness, fine grain size and overall economy.

Each Ni-Vee bronze provides special properties. Type A gives extreme strength. Type D furnishes very high resistance to seizure and galling. All types show little dezincification or stress corrosion under corrosive attack.

### Informative booklet on Ni-Vee bronzes

"Engineering Properties and Applications of Ni-Vee Bronzes" covers alloy compositions, strength properties, resistance to high temperatures, corrosion, wear, along with other helpful information. Write us for your copy.

\*Registered trademark

THE INTERNATIONAL NICKEL COMPANY, INC.  
67 Wall Street  New York 5, N. Y.

# NI-VEE BRONZES

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Circle No. 133, Pages 141-142

# Looking at Business with Modern Castings

This is a nervous period for most metalcasters. Mixed reports are coming from Detroit and the steel makers. Labor's attitude is not helpful. Bankers indicate a leveling off for a few months--although this may be taking the conservative view.

Gains are anticipated in production, construction, income and sales. Our guess is that the pace will not be as fast as in recent months, but you must look at previous bench marks to evaluate the outlook for the remainder of 1961. Most steel-using industries are expected to step-up their orders.

There's more reason for optimism than current events would have you believe—Berlin notwithstanding. The climate is right.

## DEFENSE

Khrushchev helped out here. New defense spending by the government should begin in time to aid industrial output the last quarter—definitely the first half of 1962. The alert notices to the reserves are out. At least \$500,000,000 more is available for new bombers and missiles. Fall-out shelters are to be built. In short, the military strength of the country is being increased, and it will stay big.

## AUTOMOTIVE

At this writing, an easing in steel orders has caused some alarm. But this is a temporary situation. Do not expect any prolonged strike if it comes. A good sales year is ahead. The dealers have cleared older models. 1962 automobiles may be in short supply depending on choices, for a brief period. The industry will reflect defense needs such as trucks and other ordnance.

## CONSTRUCTION

Gains are continuing. In fact the value of new construction activities reached a record high in July. Governmental action will mean even greater gains. Congress has legislated easier terms for private loans guaranteed by the government, and more money for construction purposes--water works, sewage facilities, gas facilities. Expect much activity in these areas: home modernization, urban improvement projects, and public housing.

## FARM EQUIPMENT

Easier loan terms in the new farm bill signed by the President can have a direct effect on the purchase of new equipment during the coming year. Operating loans . . . for equipment, livestock, feed, etc., can now be made in

**where carbon control counts...**

**count 5**

and choose the ABC Foundry Coke that meets your particular cupola requirement. Only ABC produces five types of foundry coke: One type for highest carbon pick-up . . . One type for intermediate carbon pick-up . . . Three types for the lower carbon pick-up requirements of malleable iron and semi-steel foundries. Each type of ABC Foundry Coke is engineered for performance within close limits and is cupola-controlled at ABC's Coke Plant.

Do you have a carbon pick-up problem? An experienced ABC service engineer will gladly discuss your cupola melting and recommend the type of ABC Foundry Coke best suited to give you closer carbon control . . . control that counts in lower cost and better castings.



**ALABAMA  
BY-PRODUCTS  
CORPORATION**

General Sales Office:  
First National Building  
Birmingham, Alabama

SALES AGENTS:

Great Lakes Foundry Sand Company, Detroit, St. Louis  
Coke & Foundry Supply Co., St. Louis; The Ranson and  
Orr Company, Cincinnati; Kerchner, Marshall and Company,  
Pittsburgh; Anselman Foundry Service, St. Charles, Illinois;  
Barker Foundry Supply Co., Los Angeles & San Francisco.

**ABC...** *'Familiar Combination For The Finest in Foundry Coke'*

Circle No. 128, Pages 141-142

amounts up to \$35,000 as compared to \$20,000 previously set as the limit. Loans to buy and enlarge farms now may be made on any family farm if the farm indebtedness is not more than \$60,000 when the loan is closed. Bigger farms mean bigger equipment! Another important aspect of the bill . . . loans to groups of farmers for the development of rural community water systems, irrigation and draining systems now have a ceiling of \$500,000 for a direct FHA loan and \$1 million for private FHA-insured funds. Previous limit was \$250,000 for both. This can inspire expansion plans by farm groups in many areas.

## MACHINE TOOLS

If Rockford, Illinois, is any indication, things are beginning to hum! Orders are ahead of 1960 thus far. Defense needs will create an even better situation in the months ahead.

## POWER TOOLS

The president of Rockwell Manufacturing Company predicts the last quarter of this year and all of 1962 should be excellent for power tools. Reasons: (1) bigger replacement market, (2) school market growth, (3) growing industrial market, and (4) continuing do-it-yourself market growth.

## TRUCKING

The cost squeeze is on truckers. In turn, they are putting pressure on U. S. truck makers to turn out trucks which cost less money. Result: More and more diesels for medium-duty trucks especially. Catch: Air pollution from exhaust fumes. Legislation by cities and states may result.

## LABOR

Job security is a big factor as far as UAW is concerned in its negotiations with the Big Three auto makers. Metalcasting management has been in a better bargaining position this far, with the industry down for so many months. This situation, according to the National Foundry Association, resulted in larger than usual negotiations and a stronger stand by management.

## CONTROLS

You'll find this an interesting subject in the months ahead. How far they will go will depend on defense needs and inflation. The plans are made. They are up-dated. Do not discount control speculation about wages, prices and production.

## BUSINESS ABROAD

If you are interested in foreign markets, and their impact on our economy, we suggest you dig deep into the implications of Britain's move to join the Common Market. Britain is not alone. More and more U. S. companies are establishing themselves over in Europe. The effect on domestic business is obvious.



# TRAMP TRAMP TRAMP

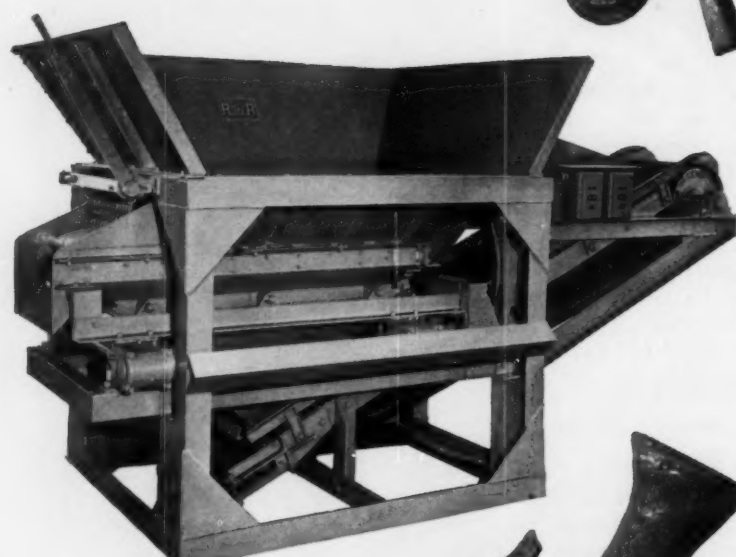
Tramp iron drops out of the picture when you install a Royer Scrap Control Unit.

If you're looking for immediate savings in your foundry operations by eliminating tramp iron damage to equipment, castings *and profit*, here's a small investment with a big payoff.

Royer Scrap Controls clean up to 60 tons of shake-out sand an hour. Because they're portable and require no pit, they'll fit your mechanization plans and give production line efficiency.



Send for Bulletin SC-61. It gives the facts and specs on the Model 522 shown and tells you about other foundry units. Royer manufactures a complete line of sand conditioning units to fit any size foundry.

Contact us at 155 Pringle Street, Kingston, Penna., phone BUTler 7-2165.



Model S-522-9M,  
one of 3 Royer  
Scrap Control Units

**ROYER FOUNDRY & MACHINE CO.**



ROYER

# Metalcasting and Washington



## Tax Legislation Lags

With Congress in its last days of the session, it appears to be touch and go on winding up action on the Administration's tax message . . . On the spot is the investment tax credit proposal which had been sought for and backed by a large segment of business.

At this moment the tax-writing House Ways and Means Committee was preparing to vote its final draft . . . Which means it still faced House action, Senate action, and a House-Senate conference.

Despite the lateness of the session and the last-minute Administration request for heavily increased defense spending due to the Berlin Crisis, Treasury Secretary Douglas Dillon is urging the Ways and Means panel to complete action on the tax legislation . . . Emphasis is focused on the investment credit plan as an incentive to modernize industry.

In a letter to Wilbur Mills, chairman of the House panel, Dillon emphasized: "the need for an investment credit to increase our efficiency and productivity is as great if no greater than when it was originally recommended earlier this year . . . I have noted with concern recent reports that domestic tool orders by American industry are lagging in part because of uncertainty regarding the timing of the enactment of the investment credit."

"Indeed," Dillon continued, "while orders by foreign producers for machine tools in this country are rising, domestic demands have leveled off and seem to be static."

At this point it's a matter of the House group reporting out the complete tax legislation . . .

It had announced approval of the investment incentive proposal (MODERN CASTINGS, August, page 43), which gives an across-the-board eight per cent tax credit on the first \$100,000 of investment, and on half of the amount above \$100,000.

Small business groups seem to favor the Administration's tax credit proposals . . . but many other business spokesmen are far from satisfied . . . They are pressing for a substantial improvement in depreciation allowances, the heart of the heavy burden.

The American Economic Foundation affirmed that the U. S. now has the lowest rate of economic growth and the second worst unemployment burden of the eight leading industrial nations of the free world . . . There is a significant relationship between these factors and the fact that U. S. allows its industry the lowest depreciation rates by far of all countries studied.

The Treasury has promised an overall study of the situation next year . . . This moves industry groups to hope for depreciation allowance improvement . . . It also appears to have the affect of putting off enactment of legislation which gives small business the same tax break on retirement investment now enjoyed by officials of large corporations . . . Or by all other employees for that matter!

## New Head for BDSA

Rumors that the Commerce Department's Business & Defense Services Administration was to be abolished by the Democrats were cut off with the appointment of a new administrator.

Commerce Secretary Luther Hodges—after a six-month delay—named Thomas E. Drumm, Jr. to the post . . . He was formerly in charge of industrial plant and personnel programs in New York, New Jersey, and Delaware and also served as command representative to the Industrial Employment Review Board of the Provost Marshal General's office.

The BDSA is composed of industry divisions which gather and disseminate information concerning the respective industries in peacetime . . . In wartime it would serve as did the old National Production Authority and decide on allocations of supplies and materials.

The delay in naming a head for this group fed the rumor that it would be scuttled . . . The House once voted to end the BDSA by refusing operating funds, but it was argued out of this action in a meeting with Senate conferees.

A reorganization is in the offing for the divisions . . . Many have direct or indirect interest to foundries. These include Iron and Steel, Miscellaneous Metals, Metalworking Equipment, Automotive and Transportation Equipment, and others . . . Future changes will be noted here.

## \$1 Billion in Pipe Lines

In a Senate Commerce Committee confirmation hearing it was recently revealed that natural gas producers have about 200 applications pending before the Federal Power Commission concerning about \$1 billion in new investment in pipe line facilities . . . This could mean a booming business in cast steel valves.

## 3 reasons why our industry has accepted Multi-Mull

### 1. QUALITY OF PREPARED SAND

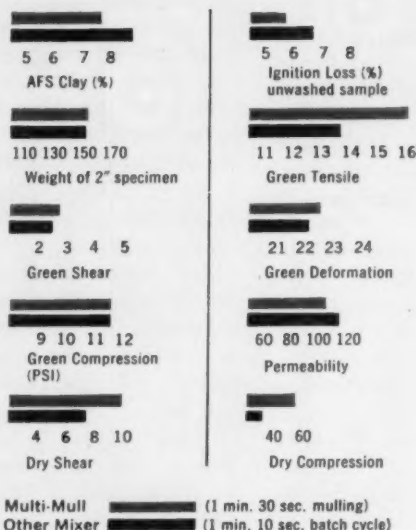
#### Test show Multi-Mull superiority

In a series of actual foundry tests (right), system sands from a Multi-Mull and another mixer are compared. The same base sands from the same foundry using the same bond slurry are the everyday product of entirely dissimilar mullers. Mulling times are shown.

The knowing sand technician sees here that which the practical man knows by "hand feel" — the Multi-Mull sand will lift better; will wash, cut and buckle less. There is more to sand quality than simple compression tests show.

The superiority of Multi-Mull sand is attributed to two factors:

1. The unique recirculation feature within the muller.
2. The sound mulling principle inherent to all Simpson mullers.



### 2. QUANTITY OF PREPARED SAND

#### It's continuous — all preparing time is used for mulling

In the Multi-Mull, time spent on weighing, batching, charging, wetting-out and discharge is eliminated... as is "pre-mull", dispersion and tempering of bonds. All time in the muller is spent in developing desired

properties in the sand being mulled.

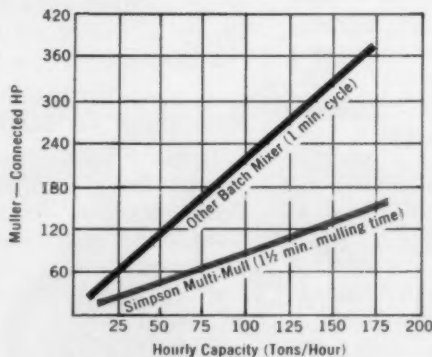
Time saved here contributes to Multi-Mull's proven ability to produce sand at the highest productive rate per dollar of investment in Mulling Equipment.

### 3. ECONOMY OF OPERATION

#### Multi-Mull can reduce the cost of sand preparing installations

Lower cost per ton per hour of capacity is only one of the important savings you can expect with Multi-Mull. Continuous mulling also eliminates batching equipment and the costly maze of multiple bins, controls and separate sand handling devices which must serve batch mixer installations. Less time and manpower is required to operate and maintain a Multi-Mull installation.

Consider: *Connected Horsepower* per ton, per hour of capacity. Examine the graph at right. Then ask your own engineers what a Multi-Mull system could save you in power supply and control costs alone.



Data taken from Manufacturer's Published Bulletins.

**SIMPSON  
MULTI-MULL®**



## **MULTI-MULL ORDERS NOW EXCEED 14,000,000 TONS PER YEAR OF CAPACITY**

After 3½ years of testing and development, the Simpson Multi-Mull was formally introduced to our industry at the 1960 Foundry Show. Now, only a year later, over 14 million tons of annual capacity in this new continuous muller has been sold.

Why has Multi-Mull gained this wide and immediate acceptance by the country's most technically advanced foundries? There are three reasons. They add up to one fact

which is significant to *all* foundrymen:

The Simpson Multi-Mull was developed for one purpose—to provide foundrymen with mulling equipment capable of *more economically* producing the *consistently* high quality sand required by advancing foundry technology. For this reason . . .

*Foundrymen who are competitively waging the battle of profit vs. cost are "tooling up" with Simpson Multi-Mull.*

*Write for literature.*



F-961-S



**NATIONAL ENGINEERING COMPANY**  
*Machinery Hall Building • Chicago 6, Illinois*

# METALGRAMS

. . . news of "Electromet" ferroalloys and metals



METALS

SEPTEMBER 1961

**SALUTE TO STEEL FOUNDRIES** -- In 1861, the first steel castings made in the United States were poured in Buffalo, N. Y. They were railroad castings, still an important application of steel castings today. This year, steel foundries observe their first 100 years of serving the railroad, earth-moving and construction equipment, rolling mill, mining equipment, military, oil and gas, automotive, and other industries. Some 275 foundries in the U. S. and Canada can pour about 2 1/2 million tons per year for these uses. Union Carbide Metals wishes the steel foundry industry continued growth and success and looks forward to serving its ferroalloy needs in the future. Your UCM representative is always at your service.

\* \* \*

**CHROMIUM STRENGTHENS CAST IRON** -- Chromium has a stronger effect on the microstructure and properties of cast iron than any other inexpensive alloying element. As little as 0.25 per cent increases uniformity, hardness, strength, and wear resistance. Larger amounts, from 0.75 per cent to as much as 30 per cent, make cast iron resistant to heat and oxidation. Chromium can be added to the cupola charge or the ladle. Union Carbide Metals produces chromium briquets and lump ferrochrome for cupola additions and crushed ferrochrome that dissolves quickly in the ladle. Ask your UCM representative for further details.

For more information circle 185 on page 141

\* \* \*

**AN EFFICIENT BLOCK** -- Why is silicomanganese the most popular blocking alloy in the steel industry? The alloy dissolves rapidly, giving faster blocks and shorter blocking times. It allows higher recoveries and closer control of manganese and chromium added to the furnace. It also improves steel cleanliness. Silicomanganese also may be used for low-cost ladle additions. For further information, write for a new 12-page bulletin, F-20,166.

For more information circle 186 on page 141

\* \* \*

**SELECT AN ALLOY** -- Are you looking for a strong graphitizing inoculant to improve the machinability of gray iron? Or a low-cost magnesium alloy to produce ductile iron? Or a low-carbon ferrochrome that will meet the low-carbon specifications of stainless steel? You can find the answers in the new "Electromet" Ferroalloys and Metals Selector that contains a complete list of alloys for steel and iron. It lists the composition and suggested use of each alloy . . . so you can select the one you need. For a copy, write for 20,119.

For more information circle 187 on page 141

\* \* \*

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation,  
270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Ltd., Toronto.

"Electromet" and "Union Carbide" are registered trade marks of Union Carbide Corporation.

## *Around the World with Modern Castings*



### **AUSTRIA**

The Austrian Foundry Institute is developing an inexpensive, simple to use, non-destructive method of assessing the properties of cast iron in all sections throughout a casting. Method depends on relationship between speed of sound propagation in iron, the elastic modulus and several other properties. A standard industrial ultrasonic flow detector can be used to determine elastic modulus, amount and size of graphite inclusions, degree of eutecticity, tensile strength, proportion of nodular graphite, and presence of flakes. The ability to determine all these properties in all parts of a casting without damaging the casting is a real boon to metalcasters who want to determine and guarantee product quality.

### **UNITED STATES**

Communication of world-wide metalcasting technology will be broadened and speeded by machine translation of Russian into English. The U. S. Army announced that a computer program which analyzes word interrelations and order for 95 per cent of all sentences is a definite possibility within the next six months. Through the use of a five-step, machine-human translation process, the entire output of Soviet technical and scientific literature—from 300 to 600 million words per year—will be abstracted and some 15 to 20 per cent of total will be translated. With this breakthrough on machine translations of Russian, other languages should be “mechanized” soon.

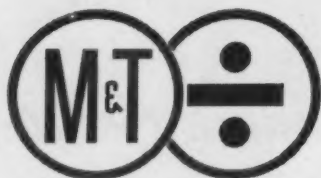
### **ROMANIA**

Surface alloyed castings in steel and iron have been produced by painting special alloy washes on surfaces of mold and cores. Three different alloying paints were used: (1) 60% Fe Cr powder, 20% Ni powder, and 20% water glass; (2) 80% Fe-Mn powder, 20% water glass; and (3) 80% Al powder, 20% water glass. Coatings were sprayed or painted to thicknesses of 2 to 4 mm. After drying, molten metal was poured into molds. Alloyed layers 0.5 mm thick were produced on surface of castings. This puts the alloy only on the surface of the casting and at the places where it is wanted. A similar trick has been used for years with tellurium—containing washes to harden gray iron. If this technique can be made to work with other alloys it opens up a vast new field of surface metallurgy and alloy economy.

### **RUSSIA**

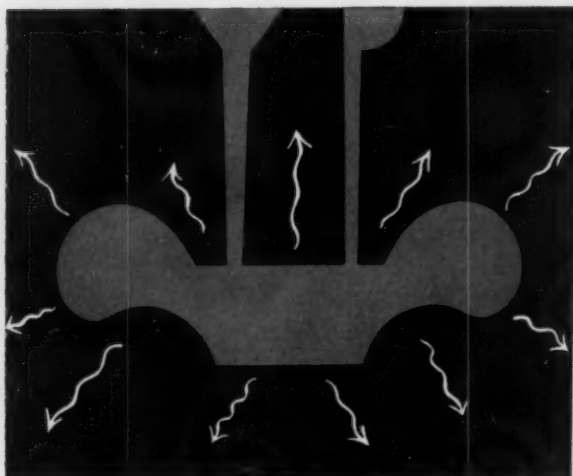
By adding 0.40 to 0.75% antimony to conventional cupola iron the resulting material has high anti-friction and anti-corrosion properties comparable to non-ferrous anti-friction alloys. In tests comparing it with bronze the antimony-alloyed iron showed 2 to 3 times the wear resistance; corrosion resistance in sea water was

*(Continued on page 16)*



**OREFRACTION**

## Zircons remove heat faster



Orefraction zircon sand conducts heat away from castings three times faster than silica sand. This property permits directional solidification of castings. Withstanding higher temperatures as well, zircon eliminates burn-in problems, especially where you have deep pockets or thin cores, and heavy sections.

In addition, Orefraction zircon toughens molds against impingement of molten metal. It gives better dimensional control. And zircon wash on the mold surface will give you an exceptionally smooth and clean casting.

Available as sand and as flour of 140, 200, 325, 400 and 600 mesh—all of recognized purity and uniformity. Ask us for the name of your local distributor of M&T Orefraction Zircons.



**OREFRACTION PRODUCTS**

METAL & THERMIT CORPORATION General Offices: Rahway, N.J.  
In Canada: M&T Products of Canada Ltd., Rexdale, Ontario

Circle No. 129, Pages 141-142

### AROUND THE WORLD

*Continued from page 15*

equal to that of admiralty brass. Sounds like this could be a cheap bearing material worth investigating!

#### GERMANY

Continuous horizontal casting of gray and ductile iron offers an interesting area for expanding metalcaster's production capabilities. A new German machine produces round bar stock in a variety of sizes with properties far superior to sand cast bars. The continuous cast iron has a fine grained matrix, fine graphite, more ferrite, freedom of shrinkage, higher tensile and elongation, and lower hardness—ideal properties for bar stock destined for machining complex shapes. Interest in the United States is indicated by the recent sale of one of these machines to the Stuart Foundry Co. in Detroit.

#### EAST GERMANY


The Central Institute for Foundry Techniques announces the development of a self-setting core and mold binder based on Didi-Leim K.P.—a synthetic resin based on ureadicyandiamide—formaldehyde. A typical mix is 97 per cent dry silica sand, 3 per cent Didi-Leim K.P., and 1.2-1.5 per cent water containing 30 grams of acid-salt hardener per kilogram of resin. Cores harden in the box in from 2 to 20 hours depending on size. Setting can be speeded to 15-30 minutes by heating cores to 160 C. It would appear that this work parallels practices in this country but with a somewhat different binder.

#### BULGARIA

Ductile iron continues to find a strong foothold in rolling mill roll applications behind the iron curtain. Roughing rolls with chilled iron surface and nodulized center give a rolling life of 35-40,000 tons compared to 20-25,000 tons for untreated iron. Carbon content is low, silicon runs around 2 per cent, nickel and chromium is added in small quantities, and a 0.54 per cent magnesium addition converts graphite flakes to the spheroidal form.

#### RUSSIA

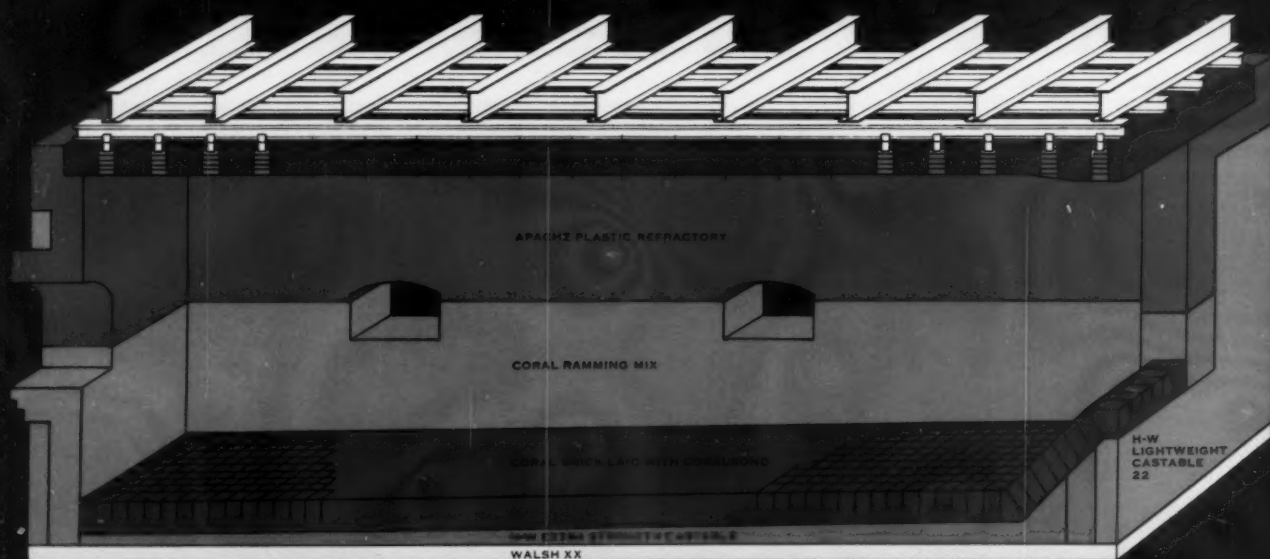
Soviet diecasters have perfected the die casting of small steel parts ranging from 1.8 to 7 ounces in weight. Electrically heated dies are held at 536-896 F and coated with a refractory wash containing 73% silvery graphite, 18% sulfate shellac (1.5-1.8 sp.gr.), 6% heat resistant clay powder (240 mm mesh), and 3% dextrine. Die life is only 300 castings. The USSR is giving considerable attention to steel die casting which is becoming a widely used production method! If there are any U. S. die casters of steel we would like to hear from you.

THIS HIGHLY SUCCESSFUL ALUMINUM  
MELTING FURNACE FEATURING MONO-  
LITHIC CONSTRUCTION WAS BUILT  
ENTIRELY OF HARBISON - WALKER   
REFRACTORIES. Construction and product details are given on the  
following page. PHOTO: COURTESY OLIN-MATHIESON CHEMICAL CORPORATION





CORAL BRICK, CORALBOND AND CORAL RAMMING MIX WERE ESPECIALLY DEVELOPED BY HARBISON-WALKER FOR ALUMINUM MELTING FURNACES. THEY HAVE ALREADY DEMONSTRATED UNUSUAL RESISTANCE TO PENETRATION AND CORROSION BY ALUMINUM ALLOY REACTION . . . AS WELL AS TO THERMAL SHOCK, SPALLING CONDITIONS, AND SEVERE IMPACT AND ABRASION. THE REFRACTORY USED IN EACH FURNACE SECTION WAS SELECTED TO ASSURE THE BEST BALANCED SERVICE LIFE.



#### WALSH XX

A strong, power pressed, high duty fireclay brick.

#### H-W EXTRA STRENGTH CASTABLE

A refractory concrete of outstanding physical strength.

#### CORAL brick, laid with CORALBOND

These specialized high-alumina brick and mortar have exceptional high strength to withstand spalling and slagging influences, and provide remarkable resistance to molten metal reaction.

#### CORAL RAMMING MIX

This companion product to CORAL brick and CORALBOND, installed by gunning or ramming, has excellent resistance to molten aluminum alloys and develops great strength at operating temperatures.

#### H-W LIGHTWEIGHT CASTABLE 22

An insulating monolith.

#### APACHE PLASTIC REFRACTORY

A high alumina (60%) monolith with refractoriness equal to brick of this class but with much lower permeability.

WRITE  
FOR  
DATA

Complete product descriptions and test data are available showing the superior resistance of these refractories to aluminum alloy reaction.

#### H-W SUPER PLASTIC

A monolith with very good refractoriness and refractoriness equal to super-duty brick.



**HARBISON-WALKER REFRACTORIES COMPANY AND SUBSIDIARIES**

GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA

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HW 61-7

## From and For the Reader...

### TECHNOLOGY FOR PROFIT

Within seven months after the appearance of the NEW TECHNOLOGY article, "Austenitic Manganese Steels," by T. E. Norman, D. V. Doane and A. Solomon (June, 1960 issue of MODERN CASTINGS) our program of producing molybdenum-bearing alloy castings was underway.

We began by producing crusher parts which were close to the configuration outlined in Norman's article. Probably our largest casting is around 2000 lbs.

No special modifications were necessary, since the material can be handled in the furnace and in the foundry with the same ease as austenitic manganese steel. Repair welding of both the 12-2 and 6-1 alloys is difficult and care must be taken to see that the castings are sound and crack-free as they come out of the mold and after heat treatment.

We find the mechanical properties of the castings produced in the 12-2 and 6-1 alloys are very similar to those outlined in the article. The significant improvement is in the tensile strength of the 12-2 alloy as compared to regular austenitic manganese steel, and this should have some benefit in reducing section size.

Production costs are still high because of the price of the additive and the poor response to repair welding. In addition, the dispersion heat treatment of the 12-2 alloy adds to the cost.

It is expected, however, that these higher initial costs will be compensated for by longer service life for the casting. Care should be exercised, in selecting the services for these castings.

Harold Rose  
Esco Corp.  
Portland, Ore.

### SHOOTERS NOT BLOWERS

We are sure you will want to correct an erroneous impression conveyed by the otherwise splendid article on "Core Production in Hot Boxes" by Philippe Jasson (July, page 55).

Mr. Jasson's article refers re-

A demonstration of WHEELABRATOR'S

## VITAL VALUES



*A minimum of three chemical analyses is performed on each heat of Wheelabrator Steel Shot to assure conformity to rigid chemical standards. Detailed laboratory analysis of microstructure further assures product uniformity.*

# Wheelabrator steel shot® consistent quality controls cleaning costs

To achieve a uniform finish in blast cleaning operations, at a relatively constant and predictable cost, and at uniform production rates, the abrasive used must be of uniform hardness and quality. Wheelabrator Steel Shot gives you this uniformity, from box to box and shipment to shipment. Its hardness, chemical analysis, microstructure and density are carefully maintained by close production controls and detailed laboratory analysis. Wheelabrator Steel Shot gives you the Vital Values of uniform cleaning results, uniformly fast cleaning speeds, reduced maintenance of your blast equipment, and uniformly low cleaning costs. Get the complete story in our Handbook of Blast Cleaning Abrasive Performance.

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STEEL ABRASIVES

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September 1961 19

HIGH SPEED CONVEYING OF BULK MATERIALS

SYNTRON

MECHANICAL

# VIBRATING CONVEYORS



## SAVE BULK MATERIALS HANDLING COSTS

Many foundries through the nation are recording big monthly savings in operating and maintenance costs by using Syntron Mechanical Vibrating Conveyors.

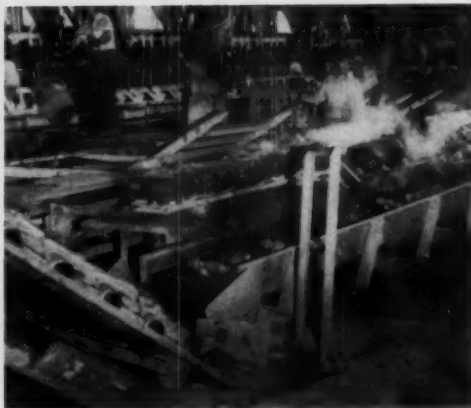
Designed to handle most bulk materials efficiently at high ton per hour rates—sand, sinter, castings, hot or cold—constructed to withstand the wear and abuse of foundry operation, built for long dependable service with a minimum of maintenance.

Syntron has a full line of types and size for every job.

Investigate the possibilities of Syntron Conveyors in your operation.



Write  
for a  
Syntron  
Catalog  
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Conveying hot castings in a modern foundry.

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Other Syntron equipment of proven dependable quality



Bin Vibrators



Hopper Level Switches

Circle No. 132, Pages 141-142



Lapping Machines

peatedly to "blown cores," "blowing plates," blowing operation," "absolutely standard blower," etc. In point of fact, all of the cores under discussion are being produced not on "an absolutely standard blower" (as American foundrymen understand the term), but on Hansberg Core Shooters—sold in the United States by Hansberg Shooters, Inc. All machines pictured in the article are Hansberg Shooters, not core blowers. As you may know, core blowers have been rendered completely obsolete in Europe by the improved-principle and more economically operated Hansberg Shooter.

We don't know whether Mr. Jason actually used the terms "core blower" and "blown cores" in his original manuscript, but we can understand why he would refer to the Hansberg as a standard core machine—because there are thousands of our machines in service in Europe including multiple installations in all of the automotive foundries.

Briefly, the difference between core blowing and core shooting is the difference between sandblasting and sand extrusion. Hansberg Shooters employ a restricted amount of compressed air as a ram or piston to instantaneously extrude a compact mass of core mix into the box. The volume of air required in "shooting" is approximately one-third the amount used in "blowing."

Superior uniformity and duplication in the shooter-made core is clearly indicated by the successful application of Hansberg Shooters in the production of grinding wheels by several American companies. Core blowers have been tried in this same application in the past with a notable lack of satisfactory results. In core blowers, the propelling air does not stay behind the sand but mixes with it in carrying it into the box. This is particularly undesirable in all core mixes (CO<sub>2</sub>, resin, furfural, etc.) susceptible to partial pre-curing through aeration.

There are about 400 Hansberg customers in this country (8000 world-wide) who know the difference between core blowing and core shooting—and who will recognize the equipment pictured.

E. H. Lueders  
Representatives  
Hansberg Shooters, Inc.

Editor's note: The Castings Congress paper was presented just as

## **Specify precisely alloyed, trouble-free, Federated bronzes**

Federated precisely engineered bronzes are produced by highly perfected alloying techniques and rigid quality control procedures developed at Asarco's Central Research Laboratories.

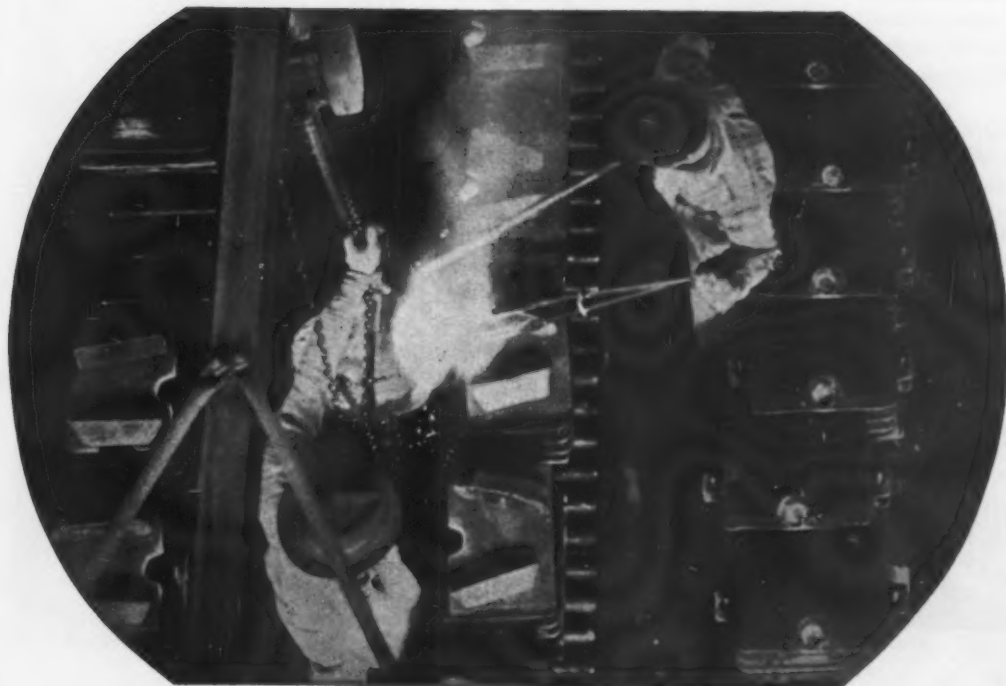
Result: Fewer rejects and more uniform castings. For best foundry performance, specify these high tensile bronzes:

**HERCULOY SILICON BRONZES** — Tough — even among the toughest bronzes. Excellent fluidity, tensile strength up to 65,000 psi, yield strength up to 35,000 psi.

**ALUMINUM BRONZES** — Tensile strength as high as 120,000 psi after heat treatment.

**MANGANESE BRONZES** — As cast tensile strength up to 125,000 psi, exceptionally high hardness.

For complete data on these bronzes, write on your company letterhead for your copy of 60-page handbook "Brass and Bronze Casting Alloys." Write or call Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y., or your nearest Federated sales office.



# **ENGINEERED BRONZES**

## Handling castings in Wirebounds cuts 7-10 hours per truck load



Foundries using Wirebound pallet boxes save 7 to 10 man hours per truck or carload over handling and shipping castings in conventional bags . . . man hours which add up to 30% savings in shipping labor for some foundries.

Besides eliminating the cost of filling and tying bags, Wirebound's large capacity and ease of handling contribute to better utilization of warehouse and loading space; simplify your order checking and inventory control.

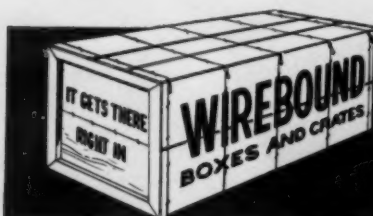
Low cost expendable Wirebounds pay for themselves by eliminating the high cost of keeping track of

returnable containers and the cost of return shipping.

Rugged Wirebound pallet boxes stack safely three and four high. They retain their natural strength even when stored outside, exposed to all types of weather.

Your customers realize savings, too, when you ship in Wirebounds. Their handling is minimized—no bags to open, no containers to return. Castings are accessible and easily identifiable at all times.

• To learn how Wirebound pallet boxes can help you realize savings, contact Wirebound box manufacturers or write to the address below.



### WIREBOUND BOX

MANUFACTURERS ASSOCIATION INC.  
222 W. Adams Street, Room 1495  
Chicago 6, Illinois

1236

Circle No. 134, Pages 141-142

the author wrote it. However, it was translated, from French to English, in this country. There is the possibility that the French word for shooting or core shooting is the same as core blowing. Core shooting, for instance, does not yet appear as a term in the cross-language technical dictionaries. The article was translated for AFS by a highly regarded expert in the sand field. Thank you, at the same time, for setting the record straight and explaining the difference between core "blowing" and "shooting."

### AROUND THE WORLD

In the June issue of MODERN CASTINGS, you mention a British process of injecting powdered graphite through the tuyeres of cold-blast acid-lined cupolas. This was in the "Around the World" section. Could you tell us where we can obtain more detailed information regarding this type of information?

K. L. Landgrebe  
Vice President  
The Wheland Foundry  
Chattanooga, Tenn.

*Editor's Note: Complete details on this process can be obtained from an article appearing in the March, 1961, issue of the British Cast Iron Research Association Journal. This is published at Bordesley Hall, Alvechurch, Birmingham, England. As a matter of fact, any of the information in the "Around the World" column can be obtained in detail if you write us. We will refer you to the source.*

### METAL-MOLD REACTIONS

An excellent approach to a complex problem which satisfies both the theoretician and practical foundryman is contained in "Factors Affecting Metal-Mold Reactions" by G. A. Colligan, L. H. Van Vlack, and R. A. Flinn, page 104 of January MODERN CASTINGS.

Detailed data present factual evidence for the conclusions reached. Castings are presented verifying the hypothetical data. It is not clear whether the authors took into account the fact that green sand molds contained water during founding while the shell molds were dry. A test using a completely dried green sand mold might prove valuable as well as one based on baked core sand.

Another significant experience would be to coat (and dry) the green sand molds with a mold wash

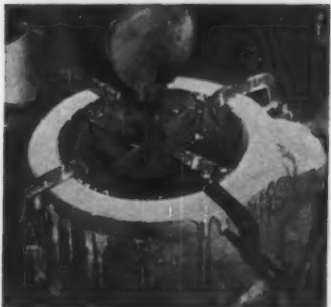
*Continued on page 25*



**GET MORE  
HEATS PER  
LINING  
WITH LESS  
PATCHING**

**POUR  
CLEANER  
METAL**

## Line your ladles with TAYCOR HYDROCAST



Above:  
Installing  
TAYCOR 414  
HYDROCAST  
in 1200 lb.  
ladle with  
the use of  
a concrete  
vibrator.  
Photo at left  
shows lining  
after being  
cast.

Iron and steel foundries in ever increasing numbers are standardizing on TAYCOR® 414 HYDROCAST® for ladle linings. These foundries report greatly increased lining life—less lining maintenance—improved quality of metal cast.

TAYCOR 414 is a corundum-base, high strength refractory castable for service to 3350° F. It contains 96% high purity alumina, sintered by a special process to give exceptionally low porosity. TAYCOR HYDROCAST has excellent resistance to erosion and metal penetration. Easily installed by pouring in place like concrete, ramming in forms; by pneumatic gun, or by trowelling.

Your savings are in the bag when you line your ladles with TAYCOR HYDROCAST. Write direct, or contact the Taylor field engineer in your area, for full details.



**The CHAS. TAYLOR SONS Co.**

*A Subsidiary of National Lead Company*

REFRATORIES SINCE 1864 — CINCINNATI, OHIO, U. S. A.

Circle No. 135, Pages 141-142



**THIS MAN HELPS MAKE TODAY'S CASTINGS  
BETTER . . . TOMORROW'S A LITTLE CLOSER**

Tomorrow we'll know how to make castings better, and at less cost. That's the dream of foundrymen everywhere. At Magcobar's Research and Development Center at Arlington Heights, Ill., better castings are more than a dream . . . they are the realistic goal of intensive research projects. When you buy Magcobar foundry bentonites, you're actually participating in these projects by enabling the foundry

research engineer shown above and others like him to continue their work to help make today's castings better, and tomorrow's castings a reality a little sooner.

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Houston 5, Texas



Continued from page 22

bound by liquid phenolic resins, rather than the usual oxygen bearing binders such as vegetable oils, proteins, sugars, and/or dextrines.

It may be possible to further minimize the mold-metal reaction by using phenolic resins of various ratios of phenol to formaldehyde, ranging from simple "one step" type containing hexamethylenetetramine catalyst through the whole suite of novolac "two-step" types containing from 5 to 15 per cent hexamethylenetetramine.

I would also like to suggest that some confusion might exist in studying figure 9 where the proprietary term might lead one to believe that resin from the shell mold is in the microstructure when actually the mounting media of the specimen is meant.

O. JAY MYERS,  
Vice-President  
Reichhold Chemicals, Inc.  
White Plains, N. Y.

#### PIG IRON AND CHILL DEPTH

The influence of the various superheating and pouring temperatures demonstrated in the experimental work in "Chilling Behavior of A Roll-Type Cast Iron" by K. E. Pinnow and R. W. Lindsay, page 75 of January MODERN CASTINGS conforms to the generally accepted beliefs. However, the conclusions that pig iron brings about a deeper chill than a straight scrap melt is contrary to long established experience.

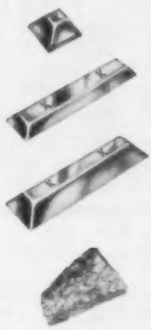
It is difficult to understand why there was chosen for this investigation a non-specification pig iron having the high sulphur of 0.058 per cent. Also, the carbon content is lower by 10 to 15 points than typical pig iron of this silicon and phosphorous content. Most chilled iron rolls today are made with a pig iron of 0.15 per cent phosphorous or less.

The composition of chilled roll iron selected for this study is not being used today except for a very small proportion of the rolls being made, largely for replacement rolls on the old "two-high" sheet mills.

It is reasonable to suspect that the inoculating effect of the granular graphite added to the all-scrap melt brought about the lesser chill, in spite of the 15 minute holding time. No graphite was added to the pig iron bearing melts. Certainly, a late addition of granular graphite has a more potent inoculating effect



The Keokuk Family, with your good in mind,  
Makes many, many tests;  
For Kemco must not ever fail  
To be the very best.



Keokuk's modern, extensive research center and pilot plant work constantly to develop new and improved Kemco alloys

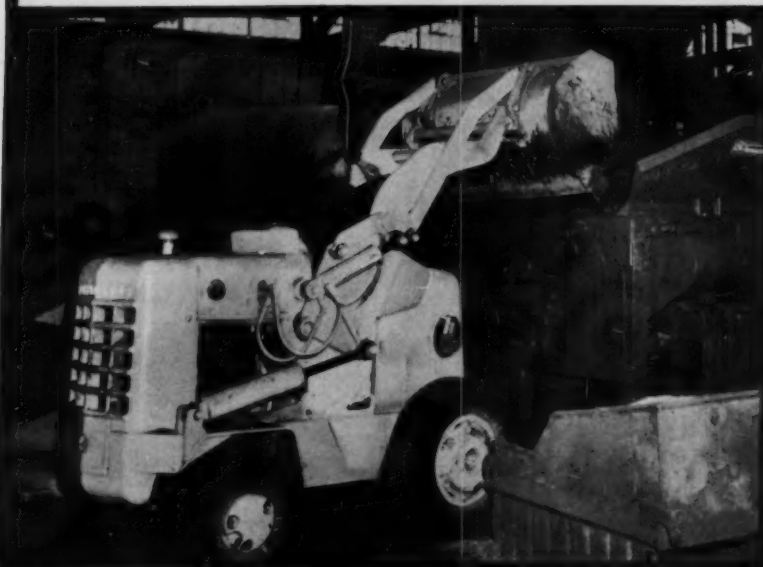
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The superior form of silicon introduction . . . available in 60 and 30 lb. pigs and 12½ lb. piglets . . . In regular analysis or alloyed with other elements. For uniform high purity, aluminum producers specify Kemco Silicon Metal.

Circle No. 137, Pages 141-142

## Here's what foundrymen say



### about this **PAYLOADER**® model

**Asst. to President says,** "We've used PAYLOADER units since 1945 and now have five HA's for over a year, working as many as 16 hours a day. They have required no maintenance other than regular greasing and similar services."

**Asst. Gen. Mgr. says,** "Our entire operation depends on the fast handling we get from our (HA) PAYLOADER units and so far they haven't let us down. For all the good service they've given us, we can't take a chance on anything less reliable."

**President says,** "We purchased our first HA PAYLOADER on a trial basis and have since bought two more. All three are working out very satisfactorily, and maintenance costs have been at a minimum."

**Foreman says,** "After some 20 months of use, the HA PAYLOADER has given outstanding service. We depend on it 11 hours a day, 240 days a year."

**Vice President says,** "The roll-back bucket is a distinct advancement over the old straight-type bucket — results in faster, cleaner operations and bigger payloads."

**Your Hough Distributor** invites you to find out how an HA PAYLOADER can speed up production and reduce handling costs in your plant. He'll demonstrate the HA's 2,000-lb. operating capacity, the 40° bucket tip-back at ground level, its single-lever bucket control and short turning radius. Other operating features on the HA include a closed hydraulic system, torque converter drive and a full reversing transmission with two speeds in either direction. Also available: Model H-25 featuring 2,500-lb. operating capacity, full power-shift transmission with matched torque converter, power steering, 6-ft. turning radius. Ask for complete details or return the coupon below.

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9-A-3

Circle No. 138, Pages 141-142

than graphite in the scrap or pig iron.

There is reason to suspect erratic conditions of melting among the various melts. With a constant ratio of charging stock, there should not have been the fluctuation in final phosphorous in the melts, shown in Table 3, which are greater than expected analytical error within the same laboratory. In the all scrap-roll melts, phosphorous should have been 0.446 per cent whereas the phosphorous content of the final melts varied from 0.402 to 0.456 per cent.

In addition, there was an increase in sulphur in the final melts which cannot be accounted for in induction furnace melts. Melting stock contained 0.108 per cent sulphur whereas the final melts contained from 0.108 per cent to 0.148 per cent.

In view of such abnormal behavior of phosphorous and sulphur, there is strong suspicion that melting conditions were not identical.

The authors in the discussion and conclusion declare that differences in carbide stabilizing effects "do not appear to be caused by differences in oxygen, nitrogen, and perhaps hydrogen content." Inasmuch as the gas content of the pig iron bearing melts were not determined, such a conclusion, with regard to pig iron, is not supported.

E. C. MATHIS  
Pickands, Mather Co.  
Chicago

### INDIAN TECHNICAL SCHOOL

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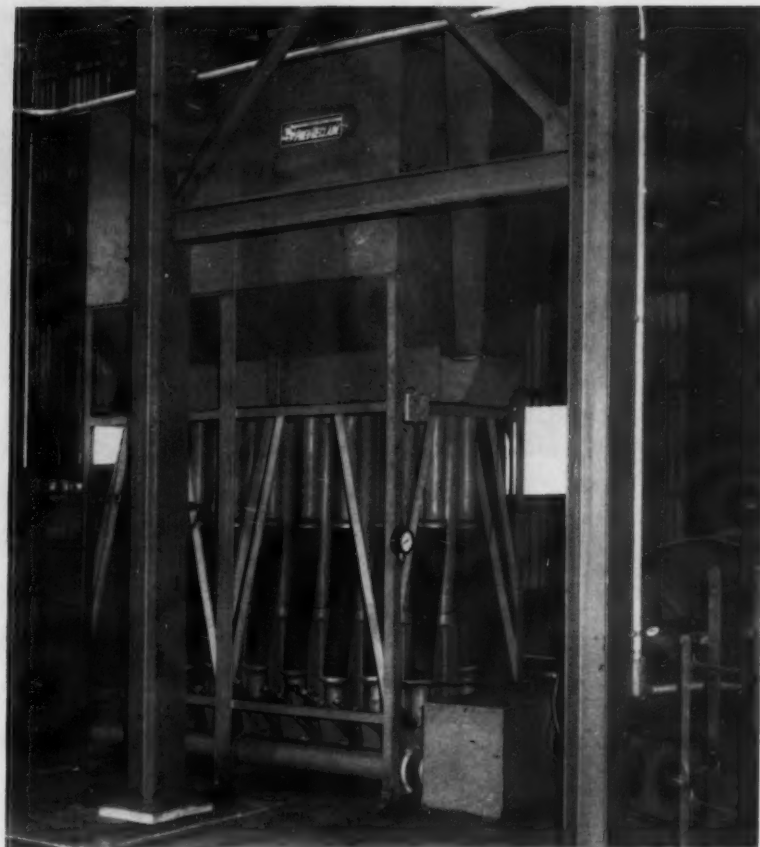
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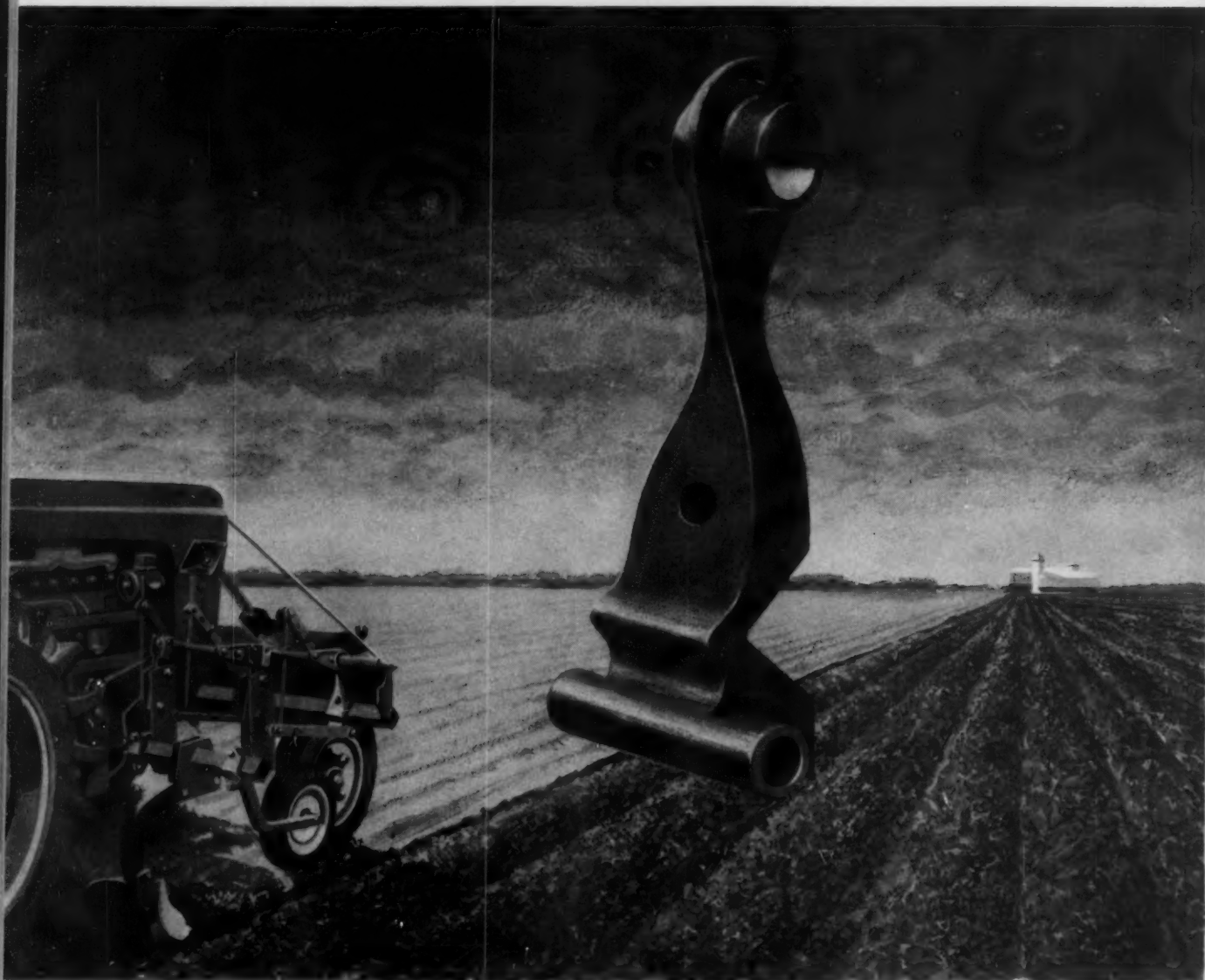
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Circle No. 141, Pages 141-142



September 1961 29



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*Facts from files of Gray Iron Founders' Society, Inc.*



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## SAFETY—HYGIENE—AIR POLLUTION

### The Air Pollution Syndrome— A Popular Misconception



BY HERBERT J. WEBER

Gilbert K. Chesterton, the famous writer, liked his libations but overindulgence made him ill. So he decided to determine the ingredient that caused the illness.

So he drank scotch and soda, whiskey and soda, gin and soda and rum and soda but always became ill. He concluded therefore from this "controlled" experiment that soda was the cause of illness since it was the one thing common in each concoction.

There seems to be similar reasoning with the air-pollution problem. When municipalities have, or think they have, an air-pollution problem, they immediately point to industry since it is common to all urban communities.

For example, a widely accepted belief in Southern California is that Los Angeles' smog is caused by emissions from a steel mill in San Bernardino County. Actually the prevailing wind is from Los Angeles to San Bernardino County rather than vice versa.

The same steel mill was criticized for damaging citrus fruit groves because oranges in groves close to the plant are smaller than those in groves farther away. In fact, it was noticed that the size of the fruit gradually increases as one moves towards the east and away from the plant.

But horticulturists pointed out that the soil near the mill is poor for citrus growth and improves as one goes east.

Here is an example of the quite popular assumption that a coincidence implies a cause-and-effect relationship.

Another factor leading to confusion of the issue is the publicity given by the press to statements of scientists who are offering an opinion with reservations as opposed to a scientific report of established facts that air-pollution increases the incidence of lung cancer.

Even though these scientists

qualify their remarks by such statements "evidence appears to be mounting that—," nevertheless the die is cast and the qualifying phrase is ignored.

Again some air-pollution officials say we can't wait till all the facts are in, and therefore we must do something now. Whether that "something" is completely useless, albeit expensive, is beside the point.

All these things lead to an uprising of the irate citizens. Then the cry is taken up by the politicians in response to the "will of the people."

It is difficult for many people to believe that the invisible exhausts from their cars is causing more smog than industry.

The hysteria, misconceptions, and doing "something" now have been called the air-pollution syndrome. This, I believe, is a good term for the situation, because a syndrome is a group of signs and symptoms that characterize a disease.

And so in the turmoil, we have groups who are truly concerned but we also have the charlatans, the fanatics and the crusaders too. Many of these ambitious groups press their crusade to a point of impairing the economy on which they depend for a living.

A small town has been defined as one that is proud of its congestion. And no town feels important without a traffic light whether it is needed or not.

This feeling is now extending to air-pollution laws. The town is not metropolitan without one, whether needed or not. I have been called in by towns that needed an air-pollution law like a hole in the head.

This, I suppose, is all part of the air-pollution syndrome and while Gilbert K. Chesterton's common denominator was admittedly facetious, it's not so funny when it results in a half-baked air-pollution law costing you needless money to run your foundry.

## You Can Teach an Old Dog New Tricks

by R. E. BETTERLEY



It has often been said: "You can easily tell a foundryman, but you can't tell him much." I don't agree. Nor do I agree with the old adage, "You can't teach an old dog new tricks."

Adult education today is increasing at an unprecedented rate. This is partially the result of the education boom created by space-age and changing technological demands. Because of these excessive demands on educational institutions, American business and industry have by necessity assumed new responsibilities in the training of needed manpower. In the foundry industry, such an effort is being extended by the AFS-Training and Research Institute. Recent reports indicate these efforts are costing American business more than \$2 billion each year. On-the-job training and adult education programs are being presented annually to over 3.5 million employees. This is a greater enrollment than exists in the undergraduate schools of all U. S. institutions.

Antiquated theories that the capacity for learning falls off rapidly as individuals age has been disproved by recent educational research. All age levels, according to modern thinking and actual program results, have the ability to efficiently grasp new knowledge.

To effectively teach adults, however, the Training Director should clearly recognize the peculiarities and ways of adult learning. These can vary considerably from the concepts of learning psychology as applied to young students.

Recent reports indicate the following as some important points to consider when teaching adults:

1. *Participation needed for learning.* The John Dewey philosophy of learning "by doing" has long expounded this approach, regardless of age. However, this need is keenly recognized when dealing with mature students. Adults like activity, discussion and participation as opposed to long lecture periods. And informality should parallel this participation.

2. *Course material must have immediate application.* Adult students must recognize a need for the material to be learned. This need is ample motivation for the learning process. It creates a desire to learn. If, at the outset, a course does not "hook" a student's immediate interest, much of the effectiveness of the entire program is lost.

3. *Variation in teaching methods should be used.* Even though this technique is good for all age levels, it is particularly important for mature personnel. Adults are easily bored and become restless when a program lacks variety and activity. Visual aids, models, demonstrations and activities utilizing multiple senses are useful tools.

4. *Background enhances and varies adult learning.* Adults have past experience as a background for new experience. Largely, this aids learning; although it can also be a detriment, depending upon the circumstances involved. New knowledge is easily learned when it "ties in" with previous knowledge. However, it may distort perception and meaning when it doesn't fit experience.

5. *Educate adults by using realistic problems.* Mature employees are problem-minded and learn faster when practical problems are used to develop solutions and basic principles. Adult students have a negative reaction to unrealistic, hypothetical problems but will respond enthusiastically to actual cases.

6. *Use evaluation as a teaching device.* Tests and grades are of debatable value when used solely for measurement. Nevertheless, they have their place if used primarily to motivate learning, and promote participation and discussion. Students, old or young, like to know if they are "on the right track" with new knowledge. Evaluation for comparative purposes, alone, is of questionable value.

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## New Books

### Industrial Furnaces

*Industrial Furnaces, Vol. 1, 5th Edition, W. Trinks and Matthew Mawhinney. 486 pages. John Wiley & Sons. An invaluable guide to the design, construction, and operation of furnaces.*

Lays down and discusses the basic principles underlying all furnace design and operation with numerous graphic illustrations and

typical examples. The new edition includes the advances and improvements made since the publication of its predecessor. Additions include a separate chapter on the theory and calculation of heat transfer within a furnace enclosure, including radiation and convection transfer to and from the furnace gases, and revisions of charts to reflect new findings and new design methods.

Contains chapters on Heating of Solids in Industrial Furnaces, Heating Capacity of Batch-Type Furnaces, Heating Capacity of Con-

tinuous Furnaces, Fuel Economy of Furnaces, Heat Saving Methods and Apparatus with Particular Reference to Industrial Furnaces, Strength and Durability of Furnaces, Movements of Gases in Furnaces, and a 42-page index.

### Engineering Fundamentals

*Engineering Fundamentals for Professional Engineers' Examinations, Llyd Polentz. 360 pages plus index; 327 illustrations. McGraw-Hill. Aimed at practicing engineers desiring to review their engineering preparatory to taking the closed-book for fundamentals portion of the state professional engineering examination.*

Covers all phases of engineering in condise detail with particular emphasis on mathematics, mechanics, fluid mechanics, thermodynamics, mechanics of materials, electricity and electronics, chemistry, and economics and investment theory. Book follows a three-step sequence. First engineering principles are defined and discussed. Next, they are illustrated through the solution of sample problems. Finally, a group of sample problems is provided at the end of each chapter, with the answers appearing at the end of the book.

### Metallurgical Guide

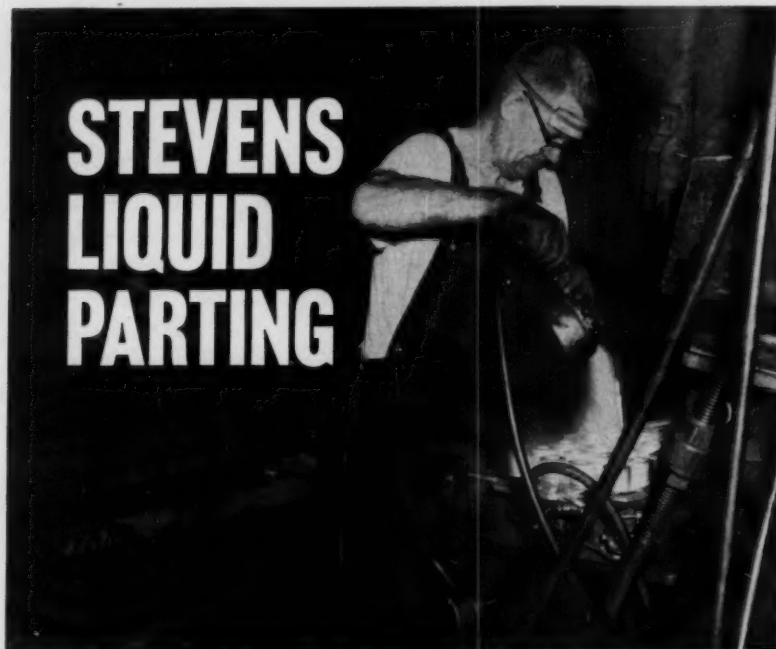
*Guide to Metallurgical Information, SLA Bibliography No. 3. 93 pages. Special Libraries Association. Describes more than 600 books, journals, and other information sources in the field of metallurgy.*

Coverage has been extended to include societies, trade associations, research institutes, government agencies, and technical services concerned with metallurgy, as well as books, periodicals, microforms, translations, and theses. The scope is world-wide, and reference sources published within the last 20 years are emphasized. Three indexes—author and agency, book and journal title, and subject—make access to the bibliographical data easy.

### Non-Destructive Testing

*Techniques of Non-Destructive Testing, C. A. Hogarth and J. Blitz. 224 pages, 139 illustrations. Butterworth, Inc. Provides fundamentals of non-destructive testing suitable for mass production techniques.*

Most of chapters are self-contained accounts of the theory and practice of electrical, magnetic, mechanical, and visual testing tech-



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niques. Other chapters are devoted to ultrasonic, radiological, and thermal comparator methods supported by thorough introductions to their scientific backgrounds.

*Production Data Book, Precision Metal Molding. Contains market research information on all precision metal molding processes.*

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#### Six Language Dictionary

*Vocabulary of Foundry Practice in Six Languages, Panstwowe Technizine, Warsaw, Poland, 392 pages. A useful book to obtain a true definition of terms often lacking in a literal translation of technical papers.*

Languages include Polish, Czech, German, English, French, and Russian. The vocabulary consists of 1232 entries with definitions as well

as 108 illustrations and six indexes covering foundry practice, physical metallurgy, and allied subjects. In particular it includes terms connected with fundamental principles of foundry technology as well as those concerning metal melting, construction and operation of foundry furnaces, preparation and testing of molding materials, mold preparation, pouring and shakeout, special methods of casting, pattern-making, and names of casting defects.

#### Cast Iron Test Specimens

*The Connection Between The Mechanical Characteristics In Cast Iron and In Separately Cast Test Specimen. 82 pages. Huettenwesen/Werkstoffkunde. Published in German. The mechanical characteristics inherent in gray cast iron are found indirectly by means of a separately cast test specimen according to the DIN testing method.*

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*History of Metallurgy, 291 pages. Describes how modern ideas on the structure of metals developed before 1890.*

The specialized history provides new facts of interest to those concerned with the broader aspects of the history of science. The story touches on the history of art occasionally and on the general history of ideas rather frequently, though its core is simply the growth of concepts of the nature of materials as they develop in the minds of men who used them. The book is well illustrated throughout with 110 pictures, drawings and graphs.

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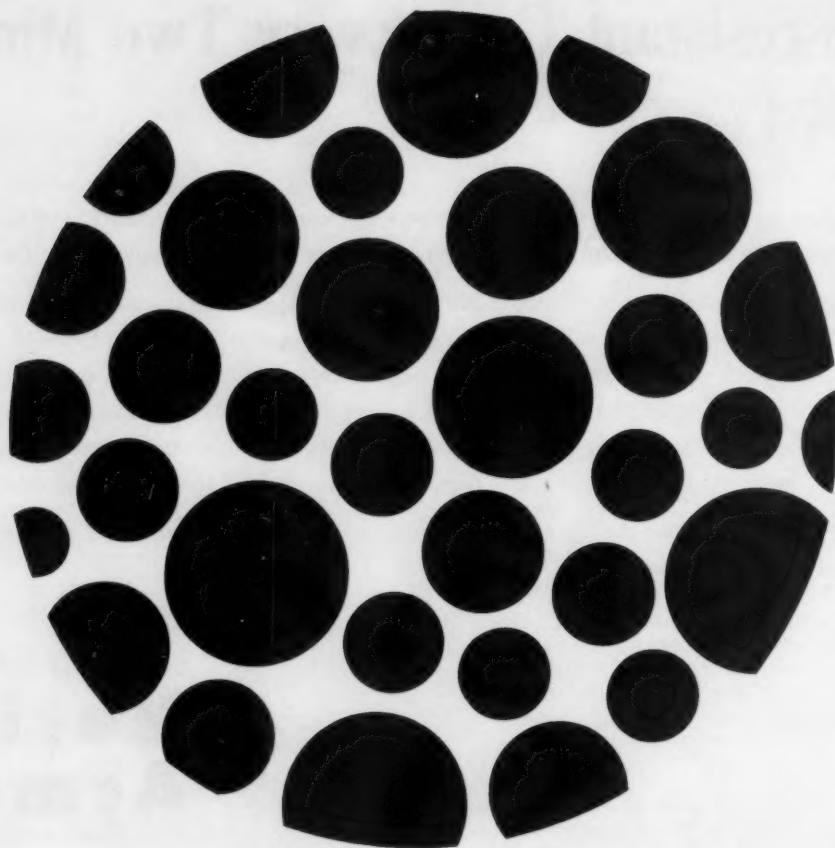
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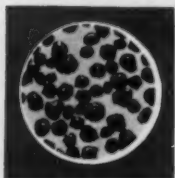
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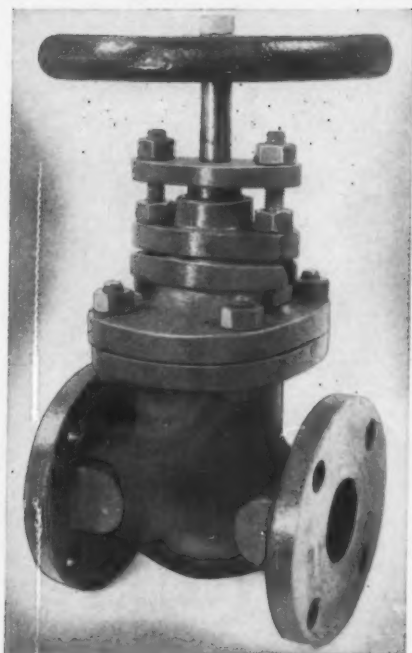
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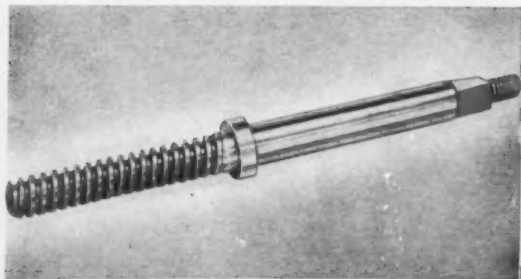
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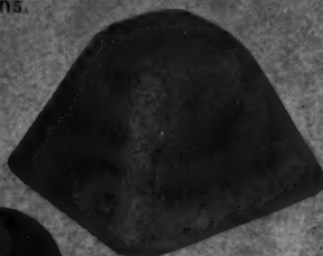
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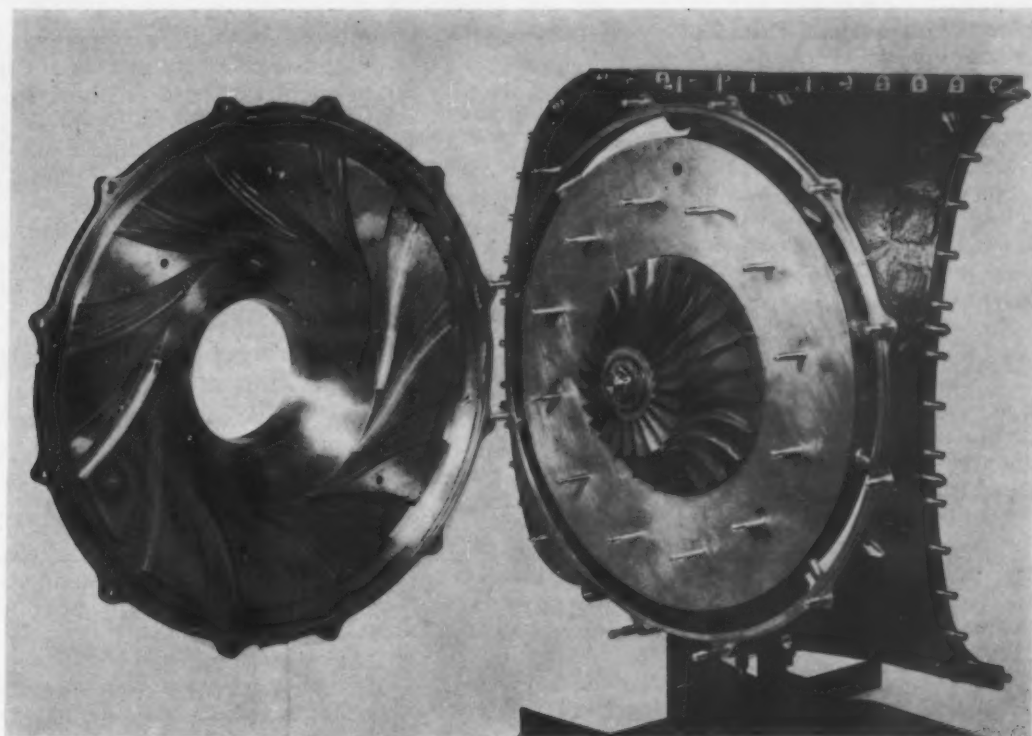


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Cast components of the experimental gas turbine engine which powers the General Motors Firebird III—car of tomorrow. A compressor cover assembly and diffuser, gassifier turbine housing assembly, and compressor impeller are pictured.

#### MARKET OPPORTUNITIES

## Selling the Automotive Casting

*Metalcasters now supply automobile makers with one-half billion dollars in castings. A sharp battle for these dollars is looming from plastics and other fabricating processes. Product improvement at the foundry level is demanded by the car manufacturers—to hold down cost and in turn to hold down the price of automobiles.*

BY JACK H. SCHAUH

**A**UTOMOTIVE MANUFACTURERS exert fierce demands on their suppliers. Not the least of these are metalcasters who, in the current model year, supplied the industry with more than a half billion dollars worth of their products—some 28 per cent of all castings sold in the country.

But competitive pressures are great. For a metalcaster to sell the automotive market he must be prepared to make the best offer in terms of quality, price and delivery.

Is this all? Indeed it is not. If metalcasters are to hold their present share of the automotive dollar much less increase that share, they must be creative and aggressive. They must know the intricacies of automotive production so well they can contribute more than a good product at the lowest price at the right time.

Metalcasters must conduct a continuing search for product improvements that will help automotive manufacturers hold down the price-cost-profit

squeeze: innovations that will repel the trend towards substitution of materials.

Are foundrymen doing these things? According to automotive industry spokesmen surveyed by MODERN CASTINGS, metalcasters are asleep at the switch.

Philip J. Monaghan, manufacturing vice president of General Motors, believes that metalcasters seem to do the poorest job of new product development and improvement of any vendor group serving the automotive industry.

American Motors Corporation probably leans more heavily on suppliers than other American car builders. George Romney, president, had this to say:

"We believe our company can progress more effectively by drawing on the skill and capacity of our suppliers.

"We intend to rely heavily on suppliers' specialization to augment our own research, development, engineering, manufacturing and capital investment in maintaining our leadership in the growing compact and small car markets. We do not plan to move into your business.

"The combination of our rising volume and your relatively low-cost existing facilities should permit metalcasters to produce more efficiently than we could produce with new facilities of our own. We shall continue to depend on you as specialists to furnish materials and products that are equal or superior in engineering, quality, dependability and cost to those of our competitors."

The situation at American Motors is not typical of operations of the "Big Three." They produce an enormous quantity of castings in their own foundries, but they too depend on outside suppliers to satisfy their needs.

### **What Kind of Castings?**

What kind of castings do automotive makers buy? Besides castings used in direct assembly, re-tooling for new models calls for new stamping dies and many are cast in gray and ductile irons. New machine tools are largely built from castings (MODERN CASTINGS, December, 1960, p 36). New die casting dies, patterns, and core boxes are being cast-to-size more and more.

No other industry has such a high rate of obsolescence in materials and processes. For example, in 1960 the controversial aluminum engine block was introduced in the Corvair. Then crash programs got underway and a half dozen other makes and models had aluminum engines this year. Some were die cast, others were permanent mold and sand cast. For the 1962 models, some car builders are already "phasing-out" aluminum and returning to gray iron. Manufacturers using a die cast aluminum block—such as American Motors and Chrysler—plan to expand their production whereas the permanent mold and sand cast blocks seem to be turning back to gray iron. (Gray Iron vs. Aluminum, MODERN CASTINGS, June, 1960, p 36.)

Castings are still highly popular with automotive engineers. They fill the bill at Chrysler Motors where engineers stress reliability, quality and low cost. Castings also simplify processing. Chrysler replaced, with one pearlitic malleable casting, a fabricated assembly of a forging, a stamping and a casting. The replacement has the required strength to replace the steel forging and the frictional properties to replace the cast iron which was needed for compatibility with the brake lining material.

Chrysler also uses alloy cast iron for camshafts and valve lifters because of excellent wear and scuff properties.

Broader applications of metalcastings by the automotive industry is primarily dependent upon these needs:

1. Closer control of dimensions to reduce or eliminate subsequent machining operations.
2. Reduced porosity in die castings to guarantee a further increase in strength.
3. Increased ductility in aluminum die castings.
4. Improved corrosion resistance for magnesium alloys.
5. Improved creep resistance for zinc alloys.
6. Improved color anodizing of aluminum die castings.
7. Development of heat treatable aluminum die casting alloys.
8. Development of an economical process for plating aluminum and magnesium die castings.
9. Die casting of ferrous alloys.
10. Economical processing of thin wall castings.
11. Development of welding techniques for pearlitic malleable iron.
12. Improved ductility of flake graphite cast irons.
13. Improved wearing qualities.
14. Increased strength with reduced weight.

Sound impossible? Until recently many of these needs might have sounded like pipedreams. But, fortunately, technology's accelerated pace is rapidly closing the gap between customers' demands and metalcasters' capabilities.

To point up opportunities for creative work in supplying auto makers, here are some of the bold new metalcasting ventures demanded in recent years.

### **Permanent Mold Engine Parts**

Most spectacular was the aluminum engine block. Chevrolet built a completely new foundry in Massena, N. Y., to permanent mold cast Corvair aluminum engine parts. The foundry is adjacent to a primary aluminum smelter which delivers molten metal directly to holding furnaces.

In 1958 Ford Motor Company constructed a "hot-metal" aluminum die casting and permanent mold facility at Sheffield, Alabama. More than 67 different aluminum parts ranging from 0.053 pounds to 24 pounds are cast in this plant.

Chrysler Corporation equipped a die casting

## SHOWCASE FOR CASTINGS

Today's automobile is literally a showcase on wheels for metal castings. Here is a list of cast parts used on a single car, the 1961 Plymouth, with a six-cylinder engine, automatic transmission, and power steering. There are 107 ferrous castings and 122 non-ferrous casting used—not including some small sub-assemblies purchased from vendors.

### BRAKES

Ferrous Castings: Wheel drums, master and wheel cylinders, wheel hubs—11 cast iron and 2 malleable iron.

### POWER STEERING

Ferrous Castings: Gear housing, valve housing, cross shaft cover, piston sealing rings, alignment wedge, reaction ring, pump housing, pump insert, front insert, front insert nut—7 cast iron and 4 malleable iron.

Non-ferrous Castings: Ball return guide, cylinder head, jacket column support, pressure control valve housing—5 aluminum castings.

### SUSPENSION

Ferrous Castings: Torsion bar anchor housings—2 malleable iron.

### REAR AXLE

Ferrous Castings: Housing, bearing cap, filler plug, differential carrier, drive pinion flange—1 cast iron and 5 malleable iron.

### TRANSMISSION

Ferrous Castings: Oil pump housing, oil pump inner and outer rotors, reaction shaft support, clutch piston retainers, clutch pressure plates, sealing rings, annulus gear supports, reverse drum reverse band lever, governor support, output flange—19 cast iron and 4 malleable.

Non-ferrous Castings: Clutch pistons, planet pinion carriers, transmission case, oil pump housing, oil pump housing cover, kickdown piston, kickdown rod guide, reverse servo piston, accumulator piston, extension assembly, parking lock lever, governor body, valve body, transfer plate—16 aluminum castings.

### TORQUE CONVERTER

Ferrous Castings: Convert hub—1 malleable iron.  
Non-ferrous Castings: Convert stator—1 aluminum.

### ENGINE

Ferrous Castings: Water plugs, cylinder block, cylinder head, piston rings, bearing caps, camshaft, valve lifters, water pump impeller, exhaust and intake manifolds, camshaft sprocket, oil pump cover, starter pinion and housing, fan pulley hub, vibration damper assembly, camshaft thrust plate, distributor counterweight, oil pump drive gear—51 cast iron.

Non-ferrous Castings: Pistons, water pump body, thermostat housing, oil pump body, carburetor body, fuel pump body, fan spacer, alternator housing, distributor housing, distributor vacuum control housing—15 aluminum castings.

### BODY AND ACCESSORY PARTS

Non-ferrous Castings: Windshield wiper gear case housing, windshield wiper vent pivot mounting, horn bodies, hood lock plunger, deck lid lock cylinder, glove box lock cylinder, door lock cylinder, ignition lock cylinder, interior and exterior door handles, exterior door bezels, interior door lock handles, window lift handle, vent window handle, vent window pivots, vent window lock plates, vent window glass frame, sun visor mounting plates, coat hooks, lighter knob, heat and radio control knobs, windshield wiper control knobs, light switch knobs, mirror mounting bracket, instrument panel bezels, heater control bezel, transmission control bezel, horn control mounting plate, steering wheel horn bar, aerial base cap nut, name plates, emblems, front fender trim strip, trim strips, instrument cluster housing, window frames—5 aluminum castings and 80 zinc castings.

facility in Kokomo, Indiana, to cast its 225-cubic inch slant-six engine for the Plymouth, Dodge Dart and Dodge Lancer. The die assembly weighs 44,000 pounds and measures 83 inches wide, 60 inches high, and 49 inches thick.

A special 2000-ton die casting machine was designed to withstand metal pressures of 8000 psi. Blocks are cast in SAE No. 303 aluminum alloy containing 3-4.5 per cent copper and 10.5-12 per cent silicon.

Cast iron cylinder sleeves inserts are cast integrally into the block. Cylinder bore centers are cast within —0.015 inches of their specified locations. Some 12,000 of these engines were cast for 1961 models and Chrysler plans to expand this number in 1962.

At a recent meeting of the Society of Automotive Engineers, authorities agreed that cast-iron cylinder liners will be used indefinitely.

Last year the Defiance, Ohio, foundry of Central

Foundry Division, GMC, became the first and only foundry to mass produce aluminum V-8 water-cooled cylinder blocks and V-8 OHV cylinder heads. These engine components are used in the Buick Special, Oldsmobile F-85 and the Pontiac Tempest.

Cast by semi-permanent molding in aluminum alloy 356, all seven sections of the permanent mold are accurately temperature controlled by water cooling.

The same foundry also produces gray iron engine blocks for cars and trucks, bearing caps and camshafts, and malleable iron differential carriers, wheel hubs and front door stop hinges.

American Motors built an aluminum die cast engine in 1961. Doehler-Jarvis Division of National Lead Company is the metalcaster.

The product is a die cast 6-cylinder, over-head valve, aluminum block weighing 67 pounds, of which 14 pounds are iron cylinder sleeves. Alumi-

num alloy ASTM S12A is used. It analyzes 11-13% Si, 0.6% (max) Cu, 1.3% (max) Fe, 0.3% (max) Mn, 0.1% (max) Mg, 0.5% (max) Ni, 2.0% other elements and balance Al. The as-cast aluminum develops properties of 25,000 psi tensile, 14,000 psi yield, and 2.5% elongation.

More than 25 per cent of American's 6-cylinder Classic series were die cast this year and production will continue in 1962.

### **Iron Casters Fight Back**

Iron casters are fighting back with thin-walled castings that rival aluminum in weight. Several aluminum blocks are being replaced in 1962 models with thin-walled gray iron blocks. For example, the present Falcon gray iron engine has an average wall thickness of 0.160 inches. A thin-walled casting would be no more than 0.10 inch.

C. H. Patterson, Ford vice president, says light weight iron engines have resulted from new precision molding techniques. Accurate thin-walled blocks are cast by using new plastic core binders (furan and phenolic resin) that cure in hot boxes and high pressure molding machines that make uniformly hard sand molds.

Patterson prefers iron because it is easy to machine, withstands high temperature, and provides superior lubricating properties.

Many foundries attribute their success to this combination of high pressure molding coupled with resin bonded cores. New designs in molding machines produce sand molds with high hardness and strength. This means virtual elimination of mold wall movement plus a smoother finish on the casting.

Resin bonded sand cores cured in the core box guarantee dimensional accuracy and high strength. Economies result from elimination of driers and core ovens. Principal benefits are the new parameters of accuracy in dimensional tolerances. Further savings result by reduction and sometimes elimination of expensive machining operations.

Improved casting quality and reliability is reflected in new car warranties that now guarantee performance for the first 12,000 miles or 12 months of service. Confidence in product quality has just been given an additional boost by Lincoln Continental's 24-month, 24,000 mile warranty.

There's a good deal of talk in automotive circles about the pending use of ductile iron in engine blocks. Ductile iron looks attractive because its higher physical properties could withstand greater stresses in even thinner sections.

Ductile iron engine-block development programs are well along at Ford, General Motors and Studebaker-Packard. There is a prospective saving of 25 to 30 per cent in weight over the conventional gray iron blocks.

This all points to a high degree of competition for automotive parts within the metalcasting industry. There is, however, a growing competition developing from without the industry that cannot

be ignored.

A new injection molded acetal resin plastic called "Derlin" is moving in fast on automotive applications. The "Derlin" instrument cluster of the 1961 Valiant represents the first plastic instrument housing and first major automotive application for this new material. The two pound plastic part replaces a 9.5 pound zinc die casting!

Over 250 decorative and functional parts on today's cars are molded of nylon. Just announced is the new monomer casting process which cuts the cost of machining nylon parts and opens new competitive possibilities.

Add to this market picture a few other processes and materials such as powder metallurgy, fibre metallurgy, glass, fibre glass, and adhesive bonding, and you can begin to appreciate the free-swinging nature of this dynamic market.

Looking into the future, here are some parts that are not now metalcastings but might well be if foundrymen apply their best creative thinking.

Door hinges	Axle components
Hood hinges	Axle gears
Heavy gage stampings	Radiators
Front wheel hubs	Gas tanks
Wheels	Door frames
Gears	Chasses
Connecting rods	Alternator pole pieces
Axles	Universal joints

The impact of compact car demands by the public has resulted in reduced tonnages of all materials going into these assemblies. Compact sales are currently accounting for about 35 per cent of new car sales. It is predicted that compact and small cars will account for more than 50 per cent of new car sales by the end of 1961!

### **Compromise Coming**

Others feel that the next few years will see a compromise between the "too small" and the "too big" so models will approach a happy medium. The public seems to want comfort and economy in a medium-sized, medium-priced car.

Featured on our cover this month is the General Motors Firebird III experimental car powered by a new regenerative gas turbine engine. The newly designed Whirlfire engine attains a fuel consumption level of 0.55 pounds per horsepower hour. Cast parts used in this unusual engine include a steel turbine wheel, bulkhead, gas-producer turbine nozzle segments, power turbine nozzle segments, lower bulkhead extension, upper bulkhead extension, and cast aluminum compressor impeller and cover assembly, and gasifier turbine housing assembly.

Built by Allison Division of GMC, applications of this engine are already being tested by potential customers in the heavy duty commercial truck, military vehicle, and marine fields.

The metalcasters' role in this field is one of constant alertness. Their biggest gains will come if they can contribute directly to the advance of the automotive product.



This shipment of fire hydrants bound for Oklahoma City is equipped with 7Zn-2Al bronze valve stems, specified by that city for all valve stems. The devel-

opment of a new alloy helped Kennedy Valve Mfg. Co. to remain competitive and hold its share of an important market.

## New Alloy Strengthens Valve Stems

*Metalcasting technology meets a customer's rigid demand by producing a dezincification-resistant alloy. Other applications already mark the alloy as one with a bright future.*

**T**ODAY A NEW BRONZE ALLOY is solving a casting problem and promising a growth market with nation-wide potential.

The alloy, 7 Zn-2 Al, was first announced in MODERN CASTINGS as a technological breakthrough, May, 1961, page 82. It is available as the direct result of rigid specifications set by the Department of Water and Power of the City of Los Angeles. In a precedent-setting demand for protection against dezincification and dealuminization, the municipality ruled out most of the qualified alloys used for bronze valve stems.

Alloys normally used for these stems—manganese bronze, aluminum bronze, or silicon brass—could not meet Los Angeles requirements because under certain conditions “soft” water dissolves both zinc and aluminum out of the alloys reducing

them to a weak, spongy, copper matrix. A broken valve stem at a time when it is needed could cause a disaster.

With no adequate sand casting alloy available to meet the demand of the specification—60,000 psi tensile strength, 30,000 psi yield, 12 per cent elongation, and no more than seven per cent zinc and two per cent aluminum—the metalcasting industry faced the loss of an important market.

Kennedy Valve Mfg. Co. of Elmira, N. Y., was one who wanted an answer to the problem. It was willing to throw its research facilities and practical experience in with that of a prominent non-ferrous ingot smelter to find the answer.

The new alloy formally unveiled at the 1961 AFS Castings Congress in San Francisco by A. H. Hesse, metallurgical engineer for R. Lavin & Sons,



1. Four stems for a six-inch valve are cast in a single mold. Two stems are fed from a single riser with gate leading metal to two risers.



2. To make drag mold-half, the riser and sprue patterns are removed from the pattern. Stems are 17 inches long requiring flasks 24 inches long.

Inc. His paper was entitled "A New High Strength Dezincification Resistant Bronze Casting Alloy." (This will be presented in *AFS New Technology* in complete detail in the December issue of *MODERN CASTINGS*.)

The new alloy, containing a maximum 7.0 per cent zinc, 2.0 per cent aluminum, 5.5 per cent nickel, 5.5 per cent iron, 2.0 per cent silicon, and 0.25 per cent lead, meets the tensile and yield strength requirements as well as the elongation test. The 0.25 per cent lead toleration is a fringe benefit. Several alloys proposed to meet the problem were able to tolerate only 0.01 to 0.03 per cent lead.

A further advantage accrues from the elimination of any need for heat treatment—a savings of close to five cents a pound over heat-treated alloys.

Both of these extra advantages are boons to non-ferrous foundries where lead contamination is always a problem and heat-treat facilities often not available.

Already Kennedy Valve is shipping valve stems made with the new alloy to a number of cities in Southern California as well as other parts of the country. Oklahoma City, where water corrosion

problems exist, specifies the alloy for all new purchases of valves and fire hydrants.

Carl Morken, vice president and works manager at Kennedy Valve—one of the men instrumental in helping to develop the alloy—describes it as "one of the most beautiful casting alloys I've ever seen in the foundry."

He points out that it needs no heat treatment, has good machinability, and offers a low scrap rate. Typical properties run 65,000 psi tensile, 33,000 psi yield, and 25 per cent ductility.

At Kennedy, bronze alloys are melted by indirect arc rocking electric furnaces. A 400-lb. charge—50 per cent ingot, 50 per cent returns—melts down in 25 minutes. When melt reaches 2200 F, 200 lbs. are tapped into a pouring ladle which is moved manually by monorail from melt room to pour off area.

Immediately after tapping, the melt is given an important degassing treatment in the ladle to remove all traces of  $H_2$  content. It takes only a small amount of this gas to lower physical properties below specification—especially the elongation.

For 30-40 seconds, low pressure nitrogen gas is bubbled through the melt to sweep out all the  $H_2$



3. For the six-inch stems, 45 lbs of the new alloy is poured. The pouring ladle moves from the melt room to the pour-off area on a monorail.



4. The castings can be removed from the mold within a half hour after pouring. Sand is easily brushed off to reveal a high-sheen as-cast surface.

gas dissolved in the molten alloy. Introduction is made through a  $\frac{1}{4}$ " wrought iron pipe immersed 8-10 inches in the melt. After degassing, metal is poured—usually around 2150 F.

In molding operations for making valve stems for a 6-inch valve, four stems are cast in a single mold. Two stems are fed from a single riser with gate leading metal to each of two risers. Risers measure  $2\frac{1}{2}$  inches diameter by  $3\frac{1}{2}$  inches high. Yield runs about 50 per cent. To make drag mold half the riser and sprue patterns are removed from the pattern. Stems are 17 inches long requiring flasks measuring  $24" \times 11" \times 3\frac{1}{2}"$ . Green sand is jolted and pneumatically rammed around the pattern. The sand mix is synthetic, containing:

- 12% Western bentonite
- 12% Southern bentonite
- $\frac{1}{2}$ % hard wood flour coated with graphite
- 2.5%  $H_2O$ .

Sand properties are:

- 183 gfn silica sand
- 26-30 permeability
- 11-13 psi green strength
- 0.020-0.022 green deformation.

Floyd Wilhelm, general foreman, explained that

the wood flour controls carbon in the sand at a level of 0.70-1.00 per cent. This ingredient leads to good peel and cushions expansion so scabs, rat tails and buckles are avoided.

Shortly after closing the mold-halves for 6-inch stems, 45 pounds of the new alloy are poured. Within half hour of pouring, the castings can be removed from the mold. Sand is easily brushed off cast surface revealing a high-sheen as-cast surface.

Ease of cutting and machining speeds the castings through the cleaning room and machine shop and on to customers.

The timely development of this new alloy helped the foundry industry "save face" in a critical situation. As time permits a longer and closer look at the new material, more applications will follow. Certainly the cavitation and dezincification problems long associated with ship and boat propellers provide a likely market. Dezincification is particularly severe in salt water, so valves and fittings on ship board represent a natural application.

The alloy's good electrical conductivity offers possibilities of electrical contact applications which are now being explored.

## MECHANIZATION! A New Report!

- *It is the best way metalcasters can remain competitive today.*
- *But it is not the entire answer!*
- *Mechanization and lower prices cannot create an increased casting requirement.*
- *For individual foundries, it can provide better price structures and adequate profits.*
- *Normally, production must be doubled or tripled to have higher total profits.*
- *This means more cast tonnage—more sales and markets.*
- *Today marginal producers, especially small plants, are on the spot more than ever.*

**M**ECCHANIZATION CAN be an answer to metal-caster's competitive problems. But it must be approached with care. Most bellwether executives believe it is the key to growth of the metal-casting industry—and the *only* way to remain effectively competitive.

This is a consensus reached by many members of MODERN CASTINGS' Trends Panel who have just been surveyed for Report No. 2. A majority say that a better sales position results from mechanization.

Since 1955, the pace towards mechanization has quickened. More than 57 per cent of the metal-caster section of the panel report they have observed "a great deal" of pick-up, and 32 per cent more indicate "some" increase. This is in all phases of metalcasting.

But, many metalcasters today are not in a position to mechanize adequately.

The biggest barrier is money. Sufficient financing is hard to get with industry conditions the way that they are today. What equipment should be purchased raises many questions. A goodly number point out that the proper marketing analysis and advice—potential markets and sales—is very important.

Government help to mechanize is not favored by many panel members—less than 25 per cent. Significantly, most think this type of assistance

should be severely limited—and recommended are remedies which should benefit *all* manufacturers. For instance:

- .... Depreciation relief.
- .... Lighter tax loads.
- .... Foreign import restrictions.
- .... Small business loans.
- .... Beneficial labor legislation for business.

The great majority of panel members want no help from Government at all. Many take the stand that Government has injected itself too far into business already.

As known for some time, the larger plants have led the way where mechanization is concerned. Those with 500 employees or more (less than 2 per cent of all metalcasting plants in the country) have gained the most. Now medium-sized plants are moving more fully into mechanization, some wisely and some not so wisely.

A main trouble spot is the small plant. What to do! How to do it? Metalcaster members of MC's panel, for the most part, agree that the small plant will become more specialized or go out of business. Some will feed off the larger plants, captive and jobbing. Indications are that there will be fewer plants in the future.

One fact is certain: *mechanization must be selective*. About 10 per cent of the Trends Panel say

the pace today is too slow. Still another segment have the opinion that mechanization is overrated, that it creates more problems for metalcasters than existed before it became an important production and profit factor. Some declare it is not worth the cost.

Many point out that the term, *mechanization*, has been too loosely handled. Not only are some metalcasters confused by what is covered by mechanization but also the difference between mechanization and automation.

It is pointed out that in the large plants the trend has been toward automation as compared to mechanization. These plants were fairly well mechanized by 1955. Currently they are automating portions of their mechanization, thus minimizing variations in hourly production.

The medium-size plants in many phases of metalcasting are well mechanized and have been for the last six or seven years. Many do not have long-range production on specific products. In such instances, automation has not taken place.

A tendency towards piecemeal mechanization by small metalcasting plants is reported. Here a four or five year program is underway.

Most panel members are of the opinion that there will always be a need for metalcasting plants that can readily adapt their output to miscellaneous job assignments. There's no one overall answer to this situation. Mechanization can help in some instances, not at all in others.

"Mechanization is highly complex," stresses one panel member. "More foolproof devices are required. Automatic machines must be kept functioning. This requires lots of maintenance and highly skilled electrical and mechanical maintenance people. There is too much *down* time on equipment!"

Another view! Mechanization has depreciated the value of the casting product more than is generally realized. Buyers have not been educated to the intrinsic value of the products as affected by:

- a. The great variety of improved metals.
- b. Greater mechanical properties.
- c. Improved surface finishes.
- d. Uniformity in dimensions.
- e. Accuracy to patterns or dies.

"Proper mechanization helps to improve quality as well as reduce costs," declares another panelist. Still another emphasizes that his plant is taking over *all* the work in a mechanized captive foundry. The reason: high costs!

It is feared by many that mechanization is oversold—and severe financial and production problems are being created as a result. Actually, the small foundries appear to be hurt the most. Some will go out of business as the pressure to mechanize continues. Others will mechanize to remain competitive. Others will merge or move into specialty fields, such as alloys.

"Much can be done short of metalcasting to make the average metalcasting plant more competitive," says one key member of the panel.

"Mechanization is no cure-all. It won't take the place of skillful operations and strong management. Most small foundries are not doing as well as they could with existing facilities."

Metalcasters should move carefully into mechanization warn equipment and supplier members of MC's panel. A department-by-department approach is recommended. In what order, here's a summary opinion:

1. Materials handling.
2. Molding.
3. Cleaning.
4. Pouring.

The most emphasis is placed on materials handling and molding by many in this group.

Significantly, most are of the opinion that mechanization is *not* for all metalcasters. When it's done, it is worth the price they say. In many instances, it is necessary to remain competitive.

But there will be problems which should be anticipated:

- . . . Labor unrest.
- . . . Equipment obsolescences.
- . . . Financial troubles.
- . . . Unbalanced production.

One very important manufacturer points out that the break-even point moves up, and that quality control problems can also be expected.

"Sound practices will dictate which way to proceed," stresses another leader. "And once the decision to mechanize a department or plant has been made, for some a complete renovation may be necessary." For others, an orderly program spread over a number of years can be best.

"Sound interest in the mechanization program by top management can help. Too often it's believed that some special assistance is necessary in order to launch such a program (financial aid, boom business). But organizations that have sound cost accounting can justify mechanization and earn increased profits for the company. Costly operations are more expensive than the replacement of equipment that can upgrade the operation."

Both metalcaster and equipment and supplier members of the Trends Panel stressed, almost unanimously, that mechanization should be *planned* and *selective*.

All should be alert to the effect of new technology, new metals, new materials, higher wages, and productivity problems. Automation should take place when practical to achieve productivity and to offset increased costs. Cost reductions in all areas is an essential.

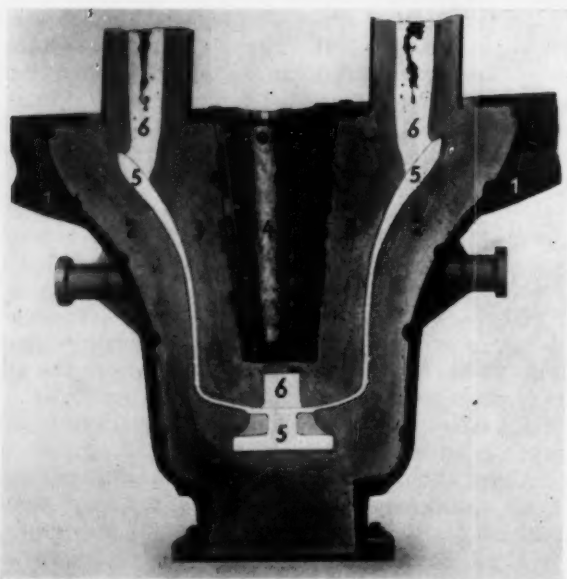
Above all: *Do not generalize about automation*. Each metalcaster must examine his own competitive position and decide where and how much, or at all. Some metalcasters should not automate. But keep in mind that the trend is toward more mechanization quickly—automation where possible. This seems to be the opinion of most MODERN CASTINGS' Trend Panel members who participated in Report No. 2.



1. Every bell produced by the Bochumer Verein foundry is tuned to an accuracy of 1/16th half tone, according to exacting standards of state and church

codes. A prolonged ringing of single bells and groups of bells is the final test for purity of tone and harmony of chimes. Faulty bells are scrapped.

## Cast Steel Bells Ring True



2. Bells are cast in an inverted position. This section illustrates the flask, mold, and core assembly, as well as position occupied by metal after pouring.

**F**OR MORE THAN 100 YEARS the firm, Bochumer Verein, a steel foundry in Bochum, Germany, has been specializing in the manufacture of steel bells.

Jacob Mayer, inventor and founder of the firm, won prizes and awards at many international fairs in the 1850's and '60s. The prize-winning bell of the Paris World's Fair of 1855 still hangs in front of the foundry's old administration building. It weighs over 32,000 lbs and has a diameter of 10 feet.

Examples of the craft can be seen and heard in the Cathedral of Paderborn in Germany and the carillon of the Bochum City Hall. The Cathedral bells have diameters ranging from eight feet to four feet and a total combined weight of 63,580 lbs. They are tuned to F-Sharp, A, B, C-Sharp, E, and F-Sharp (octave). The City Hall carillon bells vary in weight from 605 lbs to 968 lbs.

Individual skill and craftsmanship is evident in the founding practice of these steel bells. There is no such thing as a production-line approach. Each bell is specifically designed for shape, size, tone, and even for the special script or ornament which adorns every casting. Some of the steps are pictured on the next two pages.



3. Core is laid up with porous brick on top of a bottom plate and contoured roughly to the shape of the template.



4. Fine grained molding material is applied in layers and smoothed down to exact shape by concentric sweep of the template.

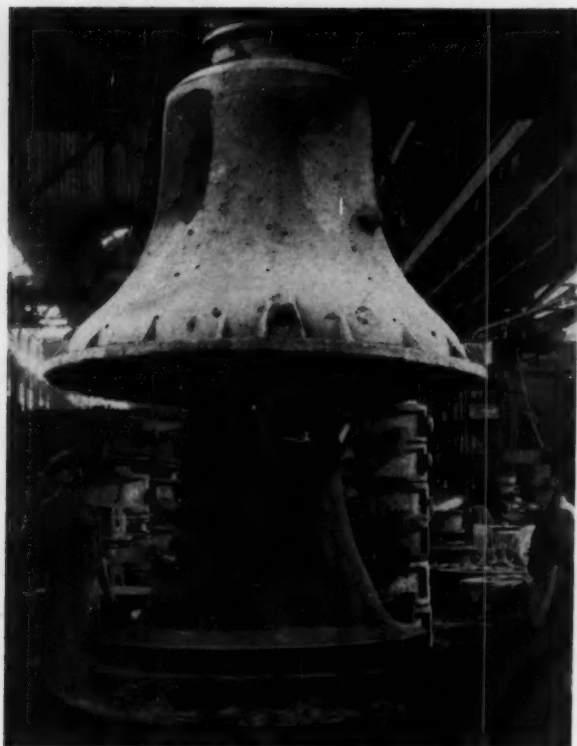


5. The mold is made in similar fashion as the core, with porous brick forming exterior contour.



6. Concentric sweeps of a template suspended from a center post shapes the mold before oven drying.

*(continued on page 52)*



7. After core and mold are dried, they are checked for exact dimension, assembled, and placed in a pit, bell top down.



8. Pouring is down from bottom-tap ladles. Cooling takes anywhere from two to five days, depending upon the size of the casting.



9. This shows the casting as it is being cleaned. The workmen use pneumatic tools for most of the basic cleaning and saw off the sprue and risers. After the bell passes the tone test, it is finished by hand.

# Fin Gating— New Cost-cutting Steel Technique

*New gating system simplifies casting procedure and helps cut many expensive cleaning and repair costs. T. Finlay of Canadian Steel Foundries, Ltd., Montreal, tells the story in his prize-winning entry in the 1961 AFS Eastern Canada Chapter Technical Paper Contest.*

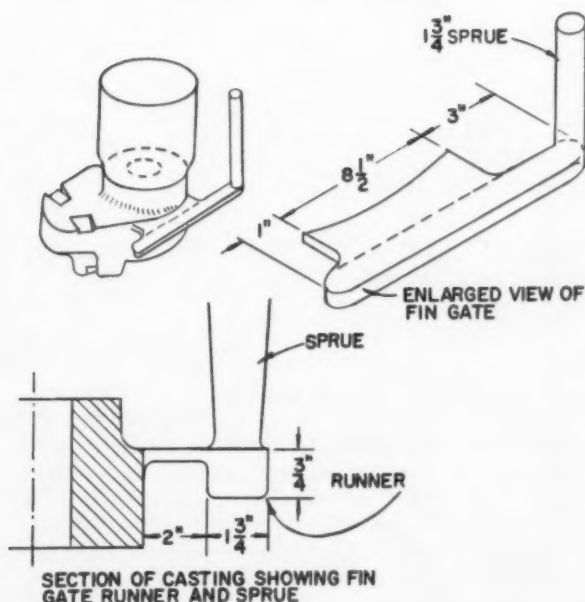


Figure 1. Fin gate adapted to a mild steel casting weighing 265 lbs.

**F**IN GATING, a new system which makes it simpler to cast difficult long, thin-section steel castings, has been developed at Canadian Steel Foundries, Ltd., in Montreal. The system assures cleaner metal going into the mold cavity and eliminates expensive cleaning and repair costs.

Scrap castings from a rash of misruns stimulated the action that culminated in this unique approach to gating. Basically it is a long thin gate located on the mold joint.

Success with the new technique led the company to convert 50 to 60 per cent of existing pattern equipment and to rig nearly 80 per cent of all new jobs with fin gates.

Figure 1 shows how a fin gate is adapted to a typical mild steel casting weighing 265 pounds. Using a 1 3/4 inch diameter sprue and a 1:1:1 ratio, we decided on a 1/4 inch fin, 8 1/2 inches long (see 1) and a runner equal in width to the sprue. At first a 1/8 to 1/4 inch thick extension to the runner was placed in the cope to trap dirt rising to the top. This practice has been discontinued as there was no apparent difference in the appearance of the casting with or without this piece in the cope.

After some experimenting, the most successful gating ratio for small and medium castings proved to be 1:1:1. This is—sprue choke area equal to runner area and ingate area equal to sprue choke area. Figure 2 is a graph simplifying the calculating of gates.

Figure 3 illustrates a more complex stainless steel casting, weighing 840 pounds, with a typical wall section 5/8 inch thick. It was essential to pour the metal as quickly as possible and still have a good surface finish free of inclusions. Welding of stainless steel is expensive, so gating was carefully planned.

Referring to the graph, a 2 1/2 inch sprue and 1/4 inch fin gate required a length of 20 inches. As the area to be filled with metal was long and thin, gate was divided into two equal portions. Each was 1/4 inch thick x 10 inches long and placed about 13 inches apart. The 13-inch separation was not calculated but merely introduced so as to spread the metal entering the mold over a larger area. The sprue was introduced to each side under the runner which measured 2 1/2 x 1 1/4 inches. A special slab core placed under the runner prevented erosion of the main body core. The results more than compensated for the extra care taken in designing the special fin gate arrangement. The patternmaker made the gate and gate core box in about six hours.

The mild steel flange shown in Figure 4 had a total cast weight per mold (2 castings per mold) of 106 pounds. Prior to fin gating inclusions oc-

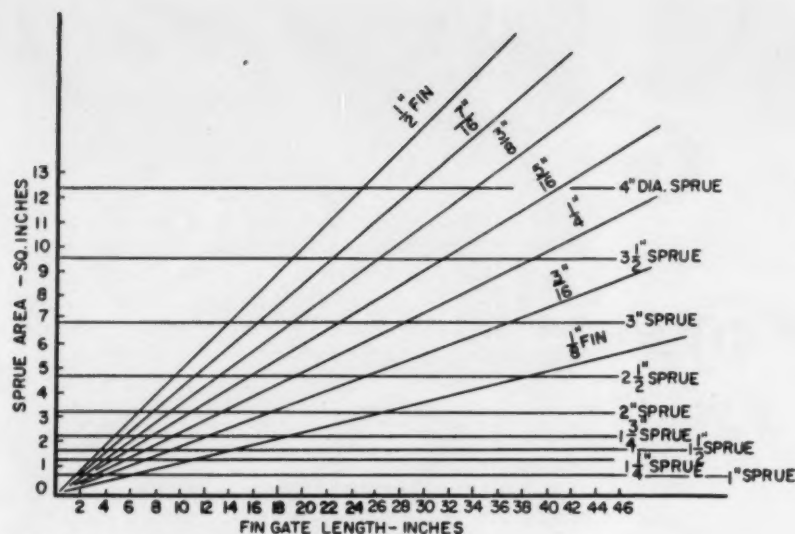


Figure 2.—This graph simplifies the calculating of gates for various sizes.

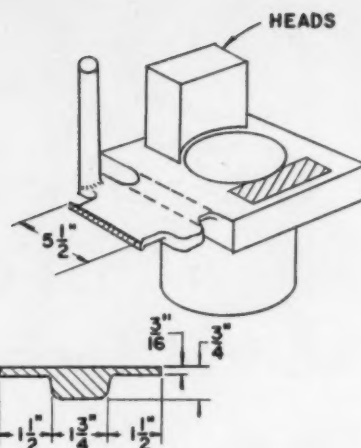


Figure 4. Mild steel flange has total cast weight of 106 lbs per mold.

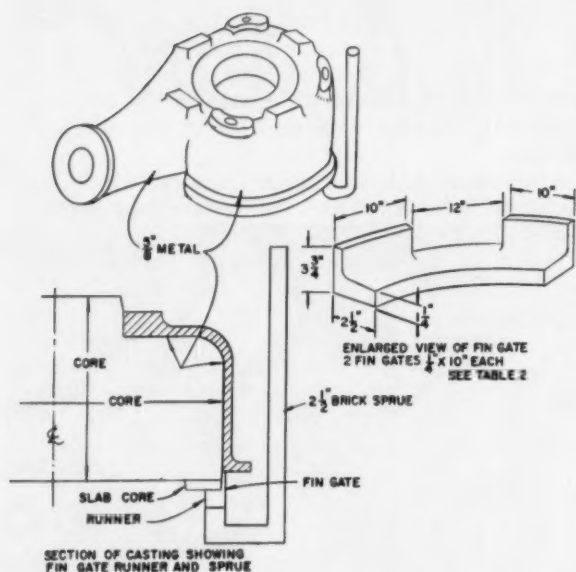


Figure 3. Complex stainless steel casting weighing 840 lbs, with wall section  $\frac{5}{8}$ -inch thick.

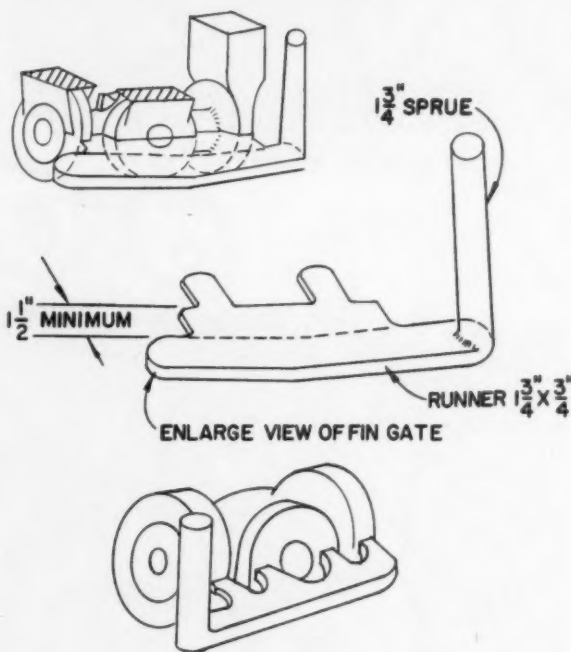


Figure 5. Unit below is former standard gating arrangement. Unit above is new gating set-up.

curved on the inside core at opposite sides from gate and about 2 inches up from drag face. Most of these inclusions had to be chipped out and casting weld repaired. From graph, a  $1\frac{3}{4}$  inch sprue,  $\frac{3}{16}$  inch fin, requires a 11.3 inch length, or approximately  $5\frac{1}{2}$  inches per casting. Sprue was placed 3 inches beyond end of fin gate; a 1-inch dirt trap and cushion were located at opposite ends. Placing the sprue 3 to 4 inches beyond the start of the fin gate yields best results. As a result of applying the fine gate inclusions have dropped.

Valves are a type of casting that presents a challenge to the foundry and cleaning departments. They are generally complicated in design, subjected to high pressure, x-rayed in critical areas, must be free of inclusions, and have a good surface appearance. Figure 5 had been our standard gating arrangement. Many acceptable castings were produced with this arrangement but always with a considerable number of small inclusions. These inclusions were not necessarily restricted to any one particular area and they involved a con-

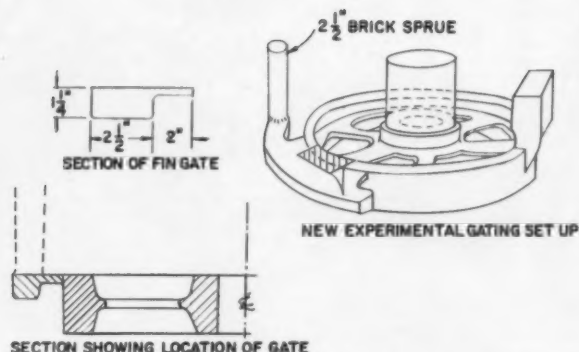


Figure 6. Fin gating used to produce gear blank which passed complete magnetic particle inspection with highly satisfactory results.

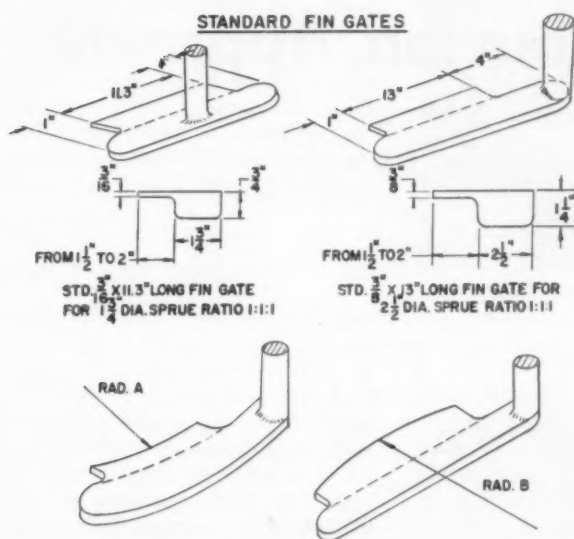


Figure 7. A series of standard fin gates have been made and marked for thickness, length of fin, and size of sprue and ratio.

siderable amount of chipping, welding and grinding before the casting reached the acceptable stage.

Figure 5 also shows new gating set-up. This sketch is self-explanatory as regards dimensions and location of gate. Castings made thus show a marked surface improvement and a reduction in the number of inclusions. We are now changing a 20 inch valve, weighing 7885 pounds, over to a 3 1/2 inch sprue and a 3/8 inch fin gate.

Gear blanks have welding restrictions on the

outside diameter where the gear teeth are to be machined. Figure 6 shows how fin gating was used to produce a gear blank which passed complete magnetic particle inspection. Results were most satisfactory—particularly around the gate area on outside rim. By consistently producing a sound and cleaner casting, we will be able to reduce the stock on the cope face. This stock is either in the form of excessive machining which the customers have to remove, or in the form of a dirt strip which the cleaning department removes.

Fin gates were next applied to loose patterns with requirements of only a few castings. By having standard loose fin gates better control of gating systems results. A series of standard fin gates were made and marked as to thickness of fin, length of fin, size of sprue, and the ratio. Example: 3/16 inch fin x 11.3 inches long, 1 3/4 inch sprue, ratio 1:1:1. See Figure 7. Each time a special fin gate was made its dimensions were marked down on a master sheet. In this way we have been able to use standard gates where we normally would have to cut gates. The standard fin gates have proved to be a great help in reducing the number of variables that exist when each molder cuts his own gating arrangement.

#### Make Long as Practical

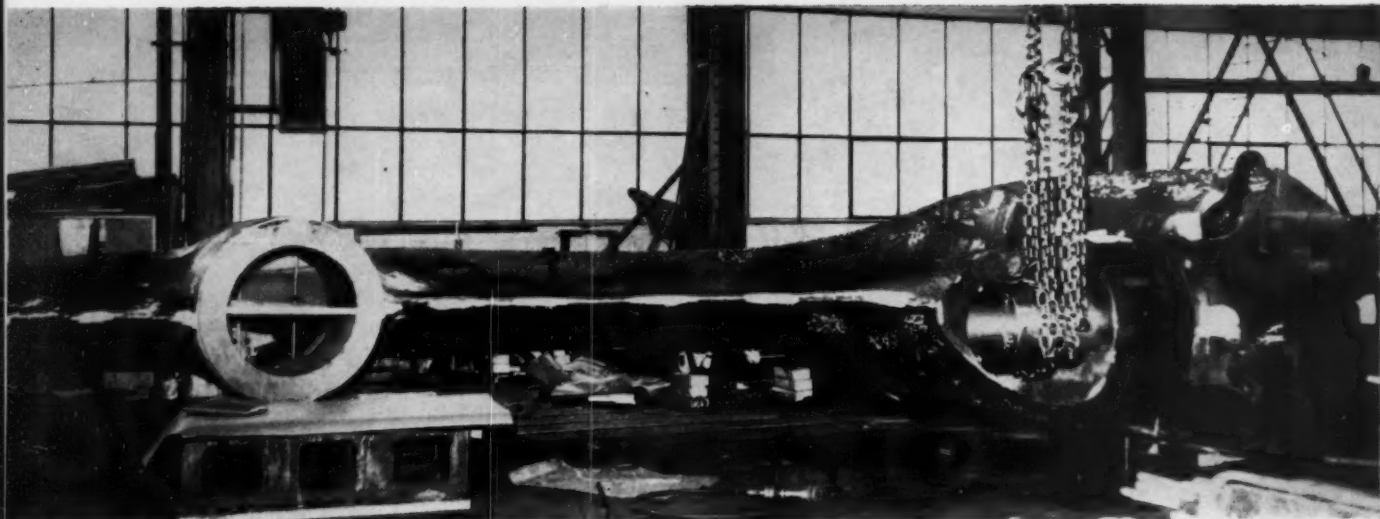
When deciding on the thickness of fin gates try to make them as long and thin as practical. The minimum suggested thickness is 3/16 inch. Good results may be obtained with a fin gate 1/8 inch thick but should the pouring temperature be low, results may be poor. The width of the fin gate, that is the distance from the runner to the casting, is kept to 2 inches width where possible. The minimum suggested width is 1 1/2 inches. Width of the runner is equal to the sprue chock diameter.

When the ratio of 1:1:1 was decided on, the sprue was placed on the center of the runner and the sum of the areas to each side of the sprue was equal to the area of the chock diameter of the sprue. Experience proved it better to have the runner extend approximately 3 to 4 inches past the fin gate and place the sprue there. No change was made to the dimensions of the runner or the diameter of the sprue, thus the ratio is 1:0.5:1 when the sprue is at the end of the runner and 1:1:1 ratio when the sprue is at the center of the runner.

Metallurgists starting out to use fin gates should take certain precautions:

1. Fin gates take more surface area of the mold than the conventional gating practice. Therefore, care should be taken with castings of large surface area at mold joint face so that sufficient bearing surface of sand exists at joint of cope and drag molds to prevent strain and possible run outs.

2. Fillets must be applied around all contact area of fin gate with the casting surface, particularly on thin section castings.



#### INTERNATIONAL TECHNOLOGY

Olivine sand is used to produce these massive 25-ton stern frame castings for ships at the Strommens Verksted foundry near Oslo, Norway.

## Olivine Wins Scandinavian Approval

*Better casting surface condition and a reduction in cleaning costs are two plus values for this popular Norwegian molding sand.*

By Professor G. S. SCHALLER  
University of Washington

**O**LIVINE SAND'S hygienic potential—as a possible safeguard against contracting silicosis—first attracted Scandinavian foundries to the molding aggregate. Once introduced, however, it quickly gained recognition for its compatibility with casting manganese steel.

With both silica and olivine in the same foundry, attention soon centered on the complete use of olivine. The changeover reduced confusion and consequently lowered costs and improved quality control.

On the credit side of olivine's ledger are lower cleaning costs, lower molding costs due to using less nails, better casting surface condition, and the hygienic aspects. The deterrent to its wider adoption has been the cost disadvantage when compared to

silica sand. As is the case with many new materials, increased use and better understanding of the product are expected to shrink the cost differential.

Olivine, which is a magnesium-iron-ortho-silicate compound for forsterite ( $Mg_2SiO_4$ ) and fayalite ( $Fe_2SiO_4$ ), occurring as solid rock in its natural state. It was first used in Norway as a by-product of refractory brick manufacturing.

The analysis of Norwegian olivine shows the following:

MgO 48.5-50.31%  
FeO 5.83-6.9%  
SiO<sub>2</sub> 40.9-41.8%  
CaO 0.62%  
Loss on ignition 0.34-0.49%

A key contribution in olivine's development came in 1946 when Norway passed an olivine law. According to this law, all olivine

rock or sand produced in Norway for sale had to be subjected to stringent quality control. This was for both sanitary as well as technical reasons, since health protection and expected castings results are dependent upon the use of a pure, high-grade olivine material. This, however, does not mean that the use of the material is mandatory.

Production of the sand in 1947, the year following the olivine control law, was approximately 4700 tons. During the next 10 years it spread in use and jumped above the 28,000-ton mark. There has been a continuing demand for the molding medium ever since.

Much of the gain in volume has been attributed to the use of olivine in Swedish foundries. In that country, foundries casting

chrome nickel, manganese steel, and mild steel were pleased with results from the sand. In Norway, one of the earliest users was the Bentse Stoperi located in Oslo. It used olivine for over 25 years, casting both gray iron and alloy steels.

Here, metal is melted in arc furnaces mounted on tracks that permit them to be retracted. During melting, the doors in front of the furnaces are closed to exclude gas and noise from the molding area.

Bentse's products include large iron rolls for paper mills which are cast in coarse No. 1 grade olivine which is heavily blacked with graphite. Stainless steels and alloy castings, on the other hand, are molded in No. 3 grain size (AFS No. 40). The total annual production reaches approximately 2000 tons of gray iron castings and upwards of 200 tons of stainless and alloy steel castings.

Although molds are faced with olivine sand much of the core work is done with silica resulting in sand heaps of unknown quality. The castings produced by Bentse are of uniform quality.

#### **Cement as a Bond**

Strommens Verksted, an electric steel foundry, is located about 12 miles outside Oslo in the town of Strommen. Its operation is perhaps the most unique of all Scandinavian foundries. Most of their castings are large since production includes many ship's components. They produce about 25 per cent of all stern frames cast throughout the world, and their sales territory includes all countries engaged in ship building.

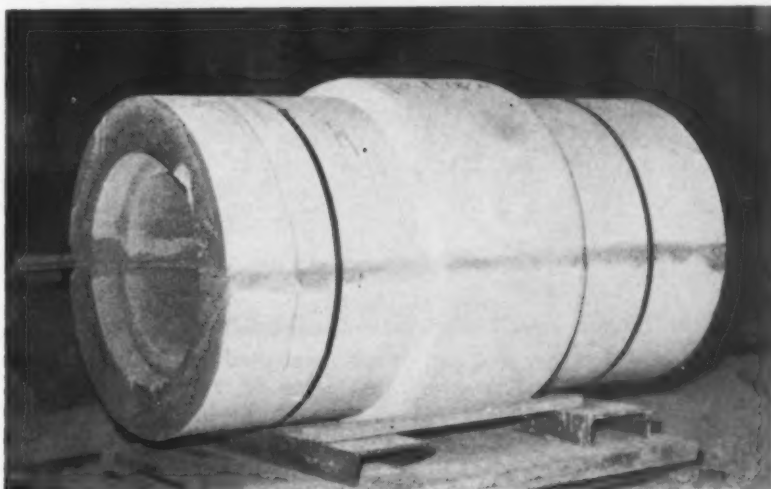
The unique operation hinges on the use of Portland cement as the molding sand bond. Mold facing sand is bonded with 8.5 per cent Portland cement together with 7.5 to 8.5 per cent water. The relatively high water content increases bench life of the prepared molding sand. No. 2 grain size olivine is used for facing; backing sand is bonded with 5.5 per cent cement and contains 10 to 12 per cent water.

Dry sand cores for large molds are also cement bonded.

Since the backing sand benefits from residual cement it has a tendency to set up rapidly. Consumption of olivine sand reaches about 75 tons a week. Large castings are molded in shallow pits. An innovation in molding is the use of reinforcing steel as chills and also molds strengtheners. Larger molds incorporate the use of gravel in order to aid shrinkage with collapsibility. Castings up to 100 net tons each have been poured

in this foundry. Daily production is approximately 25 net tons, with 90 per cent mild steel and the balance stainless.

A nominal tonnage of small work is cast in olivine bonded with bentonite. This mix contains 123 pounds of new olivine, 70 pounds returned olivine, 7.5 quarts of western bentonite, 26 pounds of fire clay, and five per cent  $H_2O$ . With this molding sand Strommens produces some remarkably intricate castings including those of closed section. They employ one technician in



Portland cement is the unique molding sand bond used by Strommens Verksted in large operations. For mold facings, the formula includes 8.5 per cent cement and 18.5 to 7.5 per cent water.



An eight-ton rolling mill pinion gear cast at the Domarfvet's Jernverk, Sweden. It was molded in olivine with a binder of Sorel-Cement. The casting required only two hours in the cleaning room because olivine was used.



Olivine sand fits in very well with mechanical sand handline gear at the Stavanger Electro-Staalwerk in Norway.

the foundry whose sole responsibility is locating gates and risers on the various molds. Some zircon wash is in evidence as are infrared lamps for drying.

The Raufoss Ammunition Works located north of Oslo also uses olivine as a facing sand consisting of equal parts of new and reclaimed olivine.

The formula is No. 3½ grain size (AFS No. 70) plus flour bonded with three per cent clay and one per cent sulphite liquor. Production totals about 2000 net tons per year of which total 1500 tons is plain carbon steel and the remaining 500 tons manganese steel. The operation uses approximately 2000 tons of olivine per year or the equivalent of one ton per ton of castings.

The Stavanger Electro-stall-verk A/S is located at Jorpeland a short distance by ferry from the city of Stavanger, Norway. This is a diversified steel operation producing both wrought steel and steel castings. Foundry activity is operated entirely with

olivine sand for the production of about 1600 tons of carbon steel, 750 tons of manganese, 500 tons of stainless and 375 tons of gray iron per year. All melting is done with a battery of electric arc furnaces which also produce the steel needed for the continuous ingot casting machine needed for their mill products operation. Such flexibility in the melt shop makes production of an extremely wide range of alloy steel castings possible.

All molding sand is prepared in an automatic sand mill designed on a unique principle employing longitudinal rolls as mulling elements. The molding operations use No. 2 screen olivine which corresponds to AFS No. 75. The consumption of olivine is approximately 1100 pounds to the ton of finished steel castings. The system sand is compounded from 220 pounds of returned olivine, 9 pounds of western bentonite and 3.5 per cent water.

Core making is also complete-

ly given over to olivine sand. A diversity of core binders are employed including the CO<sub>2</sub> technique. Some baked cores are produced from a formulation consisting of 220 pounds No. 2 olivine, 11 pounds bentonite and 5 per cent water. Large cores are generally produced by the use of a self-setting binder.

Stavanger Steel also has a shell molding operation which produces magnets cast in Alnico melted in induction furnaces. Coated silica sand is imported from England for this operation. Once a new shell molding plant comes into production, they intend to prepare their own shell sand. The combined foundry operations are only a part of their steel operating capacity since they also operate forge works and rolling mills.

#### *Health Comes First*

In Sweden, first consideration is given to the hygienic potential of olivine and mechanical and physical properties rank second. Swedish foundries range somewhat larger than in Norway, although the type of production is parallel. Olivine sand costs more in Sweden because of additional transportation expense.

A. B. Bofors, a munitions maker, has diversified to the point where munitions now constitute a relatively small part of the product output. This has come about because of the expansion of rolling mill and forge plant operations. Bofors' interest in olivine is limited to manganese steel casting production where this aggregate is used as the basis of the mold facing material. While the foundry output reaches 4000 tons per year of steel castings in all grades, manganese steel production is comparatively small. This foundry installed a mechanized line in 1928 which is reported as the first such installation in the country. The largest casting produced is about 20 tons gross weight.

Avesta Jernverks at Avesta, Sweden, operates a steel mill complete with continuous rolls where strip and sheet stainless are produced is a recent addi-

tion. A precision casting operation at the main factory is of considerable significance both as to scope and product. Olivine has been employed for quite some time, but confined to only a small part of the entire production.

In July 1960, the entire foundry was emptied of molding sand and olivine was installed so that it is now the basis of all molding and core making requirements.

In the present molding activity they use Norwegian olivine of a mean particle size of 0.27 mm which is bonded with two per cent western bentonite and one per cent dextrin and tempered with water. Due to good heat and fracture resistance of the olivine sand they are using 100 per cent return sand for facing material. As a result of this procedure, only small additions of makeup sand are added to the system a few times during the month. This also means that the facing sand binder requirements are extremely low, on the order of 0.4 per cent bentonite and 0.4 per cent dextrin. The backing sand is prepared with water and no additional binding material is added. An innovation at Avesta is that olivine sand is pretreated in a rotary kiln furnace at 1830 F.

#### **Oil Solves Problem**

In some instances difficulty of shake out has been encountered due to poor collapsibility of the molds. This has been resolved by adding small amounts of core oil to the returned sand. Production reaches about 1000 tons a year of highly alloyed and stainless steels, and runs largely to propeller blades, hubs, and water turbine buckets of several designs.

A leading pioneer in the use of olivine in Sweden was Kohlsva Jernverk, located in the town of Kohlsva. Production is approximately 3500 tons of steel castings per year of which 2000 tons are devoted to manganese steel. In this latter category, they are casting shovel dippers, weighing as much as 12 net tons each with rib sections attaining a thickness of three inches. The

facing sand used for manganese steel is compounded from No. 3 grain olivine with 2.5 per cent clay and 0.5 per cent dextrin tempered with five per cent water. It is the intention to go completely to an olivine system sand in order to eliminate entirely the necessity for facing sand. The shell molding installation is designed for 1000 tons of steel castings per year. Olivine is being used experimentally in this development with a view toward ultimate adoption.

The most widely known foundry using olivine in Sweden is the Domnarvets Jernverk located in Domnarvet where it is part of a large steel operation.

#### **Research Backs Olivine**

Olivine was originally introduced into this foundry as a hygienic measure. However, management introduced a research program that proved olivine so suitable it is now used entirely.

Some 250 production employees produce 4000 tons of carbon steel plus 400 tons of alloy steel annually. Carbon steel castings weighing 104 net tons each are poured successfully in olivine. Facing sand contains two per cent bentonite, one per cent dextrin and six per cent water. When molds are to be dried the moisture content is lowered about 50 per cent.

At the time this foundry was using silica, sand consumption amounted to one ton of silica for each ton of castings produced. As a result of an intensified research program, proper grain size selection, and behavior of olivine, they reduced the consumption of olivine to 0.2 tons per ton of castings produced. This figure represents the most economical use of olivine encountered in any foundry in Scandinavia.

A rolling mill pinion gear weighing eight net tons is molded in olivine employing a binder of five per cent MgO, five per cent  $MgCl_2 \cdot H_2O$  plus five per cent  $H_2O$ . This bond, termed Sorel-Cement, has attracted considerable interest in Sweden. As an example of the economy of using olivine, this casting re-

quires only two hours in the cleaning room as compared to more than 15 hours when the same casting was made in silica-base sand.

Another foundry pioneering the use of olivine in Sweden is the Abjorn Anderson Co. of Svedala. The casting production in the steel foundry reaches 3000 tons per year of which 1500 tons is manganese steel.

An innovation here is the use of cross walls or bulkheads to separate foundry departments. Noise, gas, and dust originating in one department is not readily carried into the next one. The shop is equipped with modern molding machines and materials handling installations. It employs 150 production workers a shift, the majority of whom are on a piece work basis.

The foundry uses olivine for cores in the following formulation: No. 3½ grain—95.5 quarts, starch binder—5.3 quarts, clay—2.1 quarts, and core oil—5.3 quarts. They also make some dry sand cores of the same formulation used for the previously mentioned facing sand. Ladles are lined with an olivine mix comprised of: 63.5 quarts olivine, 12.7 quarts magnesite, 6.4 quarts fire clay, suitably tempered with water. They are one of the few companies that are currently using olivine ladle linings.

The output of this foundry is used entirely by the parent company for road machinery and some processing equipment.

There are other Scandinavian foundries using olivine but operations are similar to those described. All manganese steel is now cast in olivine sand in Sweden. Satisfaction is apparent since every operating Scandinavian foundry adopting olivine has continued its use. This development is significant since per ton cost of olivine is substantially higher than silica or other locally available molding sand aggregates.

A spirit of cooperation and willingness to share knowledge exists throughout the Scandinavian countries, adding to the quick development and extended use of new technology of this nature.

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Circle No. 151, Pages 141-142

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Circle No. 182, Pages 141-142

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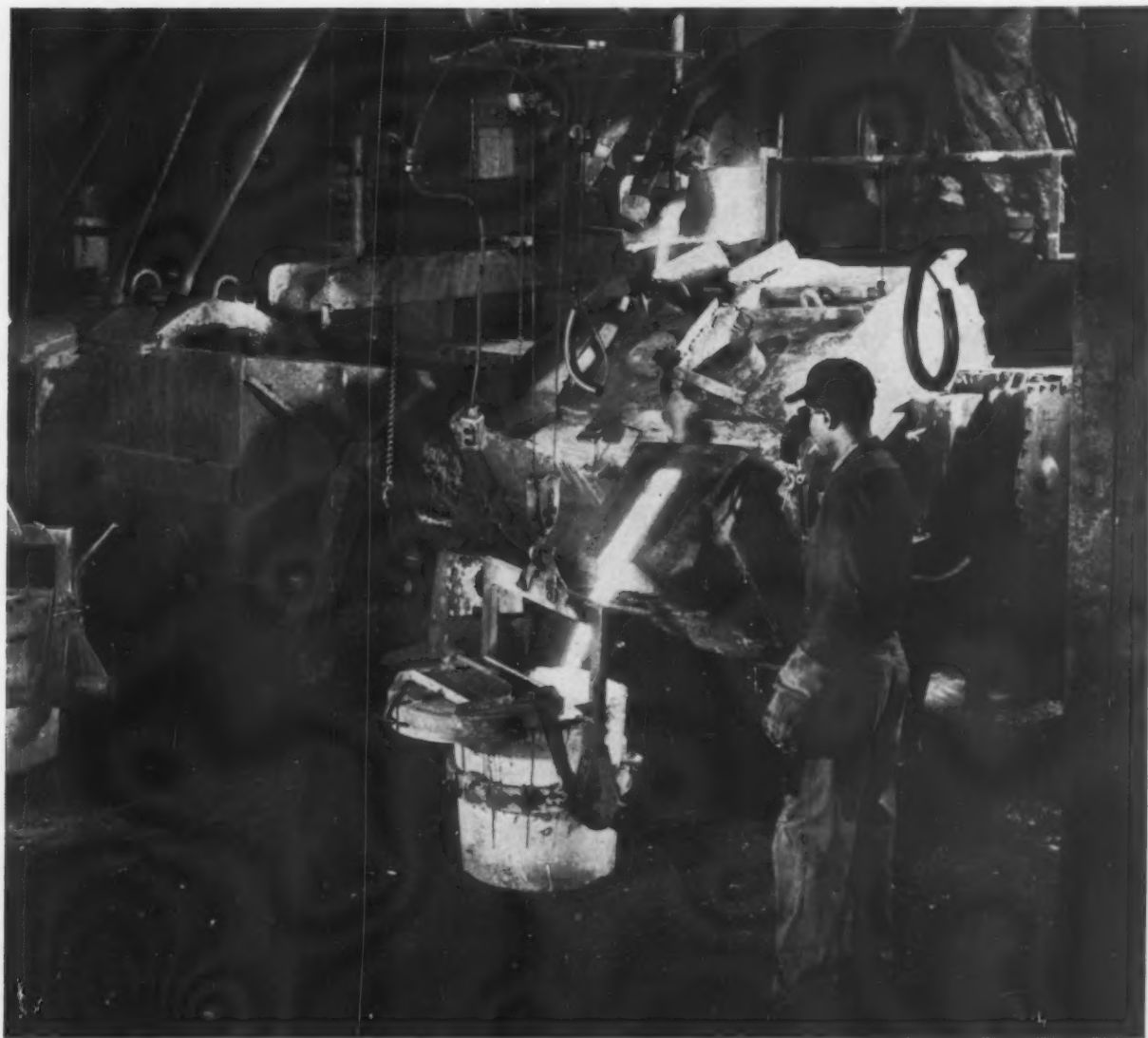
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Circle No. 157, Pages 141-142

September 1961

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# New Technology-1961

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### About The New Technology

Here are 64 more pages of New Technology—selected breakthroughs in the metalcasting field which appear exclusively in MODERN CASTINGS in 1961.

Interpretive summaries of all New Technology for 1961 appeared in the May issue (pages 69 to 84). The articles are published for the first time since their presentation in San Francisco at the 65th Castings Congress.

These breakthroughs are the

most important new technological advances in metalcasting. They were authenticated as new contributions by a 600-man technological committee guided by a member of the editorial and professional staff, S. C. Massari, AFS Technical Director. The section is edited by M. C. Hansen.

All New Technology is further evaluated by MODERN CASTINGS editors for their significance as practical tools today.

# PRECISION IN THE FOUNDRY

by A. Short

## ABSTRACT

This paper discusses what is meant by precision when related to castings. The author believes it is generally accepted as meaning dimensional accuracy, but it should be related to surface finish, definition of detail, metallurgical soundness and general section thickness, all of which vary greatly with the alloy being cast and the method used or the process available in the foundry. The paper discusses methods available for obtaining the above broad definition of precision in alloys of magnesium, aluminum, iron and steel and refers to sand casting, die casting, the lost-wax process, shell molding and the CO<sub>2</sub> process.

## INTRODUCTION

In the author's opinion there is no such thing as a dimensionally accurate casting, and no foundryman would warrant that a casting was accurate to the drawing in all respects. Many castings are held to within a close tolerance, and some firms are able to advertise truthfully that they can make close-tolerance castings in various alloys.

During the last decade the impression has been given or assumed that the investment casting process using expendable patterns would make precision castings. Nothing is further from the truth. Such castings are no more accurate than sand castings.

The author would concede one exception among all the methods and processes used for making castings—pressure die casting. Unfortunately, this is restricted in the number of alloys that can be used, but it is possible to obtain castings on a repetition basis of a high order of accuracy.

The term precision, when related to a casting, comprehends good surface finish, fine definition of detail, intricacy of design and close tolerance limits. It could be extended to cover the achievement of thin sections in alloys which are difficult to cast, to pass x-ray examination as well as any of a number of non-destructive tests.

There is no single process capable of making castings to this standard in weights ranging from ounces

to tons in the multitude of alloys specified. The foundryman is left to choose the right process for the job, having uppermost in his mind that it must be the cheapest process compatible with the customer's requirements, whether they are of soundness and strength for engineering applications or high quality surface finish for the domestic market.

## DIFFICULTIES IN OBTAINING DIMENSIONAL ACCURACY

Some difficulties in obtaining dimensionally accurate castings are:

- 1) It is virtually impossible to make calculations at the drawing board stage which will forecast the metal contraction in all directions of a cast component. Ultimate accuracy is obtained by painstaking modifications to pattern or die equipment in relation to dimensional proof reports. Having modified his equipment to give an accurate casting, the foundryman has then to contend with the day-to-day variables in materials and conditions which will give rise to dimensional variations. An obvious example is the time lapse between casting and knocking-out, which will give varying physical properties as well as varying dimensions for the same casting. Others are the amount of pattern rap, metal temperatures and sand control.
- 2) Many alloys are subject to high temperature heat treatment to obtain optimum physical properties and any accuracy maintained by the foundry in the as-cast state is lost through distortion, erosion or growth.
- 3) The achievement of accuracy is expensive and no casting should be specified to closer tolerances than are functionally necessary.

As the designer becomes more appreciative of foundry problems, the making of castings for aero engines, for example, is made less difficult by the specification of minimum dimensions and maximum weights, or in the case of development engines target dimensions and tolerances, the final tolerances being

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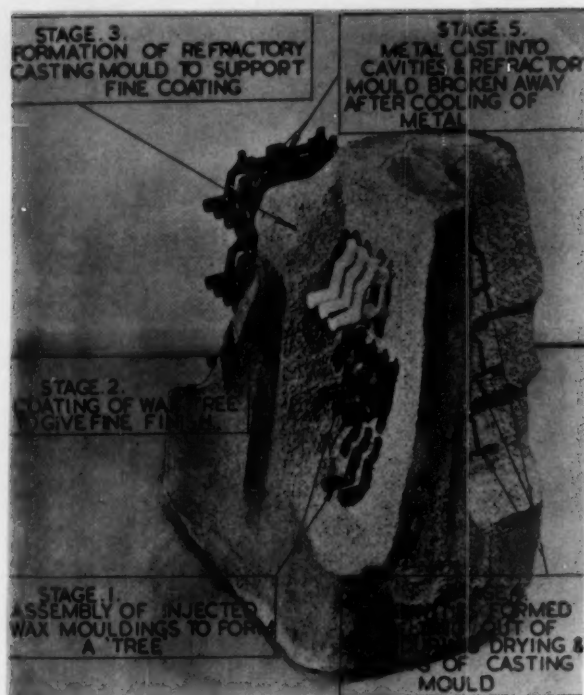


Fig. 1 — Stages in the lost-wax process.

specified for production only after foundry experience has been gained in casting the part.

It is not unusual to find that a particular part of a casting has to be thickened to make a component sound. The surplus material is then machined off to the dimension required by the customer. One wonders if it is an idle dream to hope that the foundryman will some day supply finished parts which would enable him to use his founding techniques to the best advantage and leave the machine shop to do the rest. Should this liberty be given to the foundryman he would probably consider the possibility of welding castings together to form an intricate design, or even coining or cold forming castings to obtain improved dimensional accuracy of specific dimensions and improved local properties. A new method available is spark erosion which will enable a component to be accepted for casting by ignoring a particularly difficult feature of the design in the cast state, and by subsequent processing to make it fully satisfy the customer's requirements.

### THE RIGHT PROCESS FOR THE JOB

Other factors inherent in a precision casting, namely, surface finish, definition of detail and soundness, are collectively associated with the alloy to be cast and the process selected for making the mold.

This paper refers to some of the newer methods of founding, particularly in relation to high temperature alloys.

A comment made by an American at a British conference last year was that sand casting had changed little since the days of ancient Egypt and would become obsolete in our lifetimes, and there are certain-

ly many new techniques available to foundrymen developed since the latter part of the last war. An important point to bear in mind is that, although these new and sometimes unusual processes have opened up a new field for castings, they are, in all cases, much more costly than sand casting techniques and should never be used when a sand casting will suffice.

The new processes have been sold to purchase managers, production engineers and designers as precision processes, with dimensional accuracy as the predominant feature. In fact, castings by these processes are becoming accurate only by the pressure brought to bear on foundries by customers who demand what has been advertised as being reasonably possible. If the same effort is put in by sand foundrymen to match all the aspects of precision, then these new processes will eventually cater for a small proportion of casting requirements.

### INVESTMENT CASTING PROCESS

The lost-wax process has been recorded in many technical papers and it is not necessary to discuss it here. Figure 1 illustrates the steps in the process.

It is accepted that complicated, thin-section castings are in everyday production in alloys that are difficult to machine. Generally, such castings are made from a wax pattern formed in one piece from a collapsible metal die. Certain designs, however, possess a complicated internal shape, and even if a collapsible core can be designed the cost is sometimes prohibitive when related to the ultimate quantity required.

Three different methods are available to produce a wax pattern with a complicated internal configuration.

Figure 2 shows a simple example of the assembly of wax patterns. The waxes are sighted and fused together. By such jointing, however, accuracy and definition can be lost. Some firms use polystyrene injection moldings instead of wax which, because of their strength, permit interference-fit assembly on mating locations.

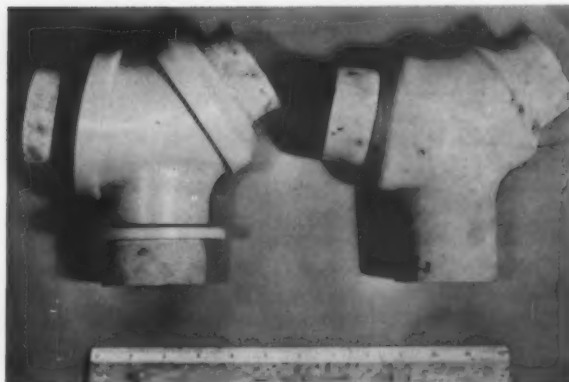
#### Split Die or Core Box

A second method is by making a split die or core box of the internal shape and injecting a pattern in a suitably filled polyethylene glycol to arrive at a wax-like model or core of the internal shape. This core is then inserted into the die and the normal wax used in investment casting is injected. Polyethylene glycol is soluble in water (more readily if the filler is sodium carbonate and the water slightly acid), and by immersing the double-injected pattern in water the inner core is dissolved leaving a wax model having a complicated internal shape (Fig. 3).

A third method is to preform the core in a CO<sub>2</sub> bonded refractory material (Fig. 4). The core is inserted in the die, the wax injected, and, after assembling the wax runner system, investment is done in the usual manner. After de-waxing, the CO<sub>2</sub> core remains locked in the mold. The following CO<sub>2</sub> core mix is typical:



Fig. 2 — Assembled wax patterns.

Fig. 4 — CO<sub>2</sub> process cores.

Material	Per Cent
Zircon granular .....	80
Zircon flour* .....	16
Sodium silicate .....	4

\*Mechanical analyses of these ingredients are:

	BSS sieve	% retained
Zircon granular .....	100	5-10
	150	70-80
	200	15-20
Zircon flour .....	200	< 20

The bond of this core mixture starts to break down at temperatures over 1500 F. If it is desirable to raise the temperature to, say, 1800 F to enable particularly thin sections to be run, the core should be soaked in a solution of hydrolysed ethyl silicate or a solution of magnesium chloride and fired before placing in the wax pattern die. This will strengthen the silicate bond given by the CO<sub>2</sub> process and render the preformed core stable at temperatures up to 2000 F.

The above three methods are now in regular use. Variations in the refractory preformed core are being developed to obtain improved surface finish and better accuracy. These include slip cast aluminum silicate bonded with refractory cements and pressed, and sintered aluminum oxide.

A further development of the investment casting process has been made in the foundry with which the author is associated for the production of large thin section castings in highly alloyed steels for incorporation into fabrications. Faced with having to make costly metal dies with which to experiment, an alternative method of producing wax patterns cheaply and quickly was sought. It appeared possible to take an assembled sand mold from the sand foundry and to pour wax into it. The bond in the sand, however, prevented the removal of the wax pattern without damage, so a special CO<sub>2</sub> bonded sand containing sodium



Fig. 3 — Soluble wax cores.

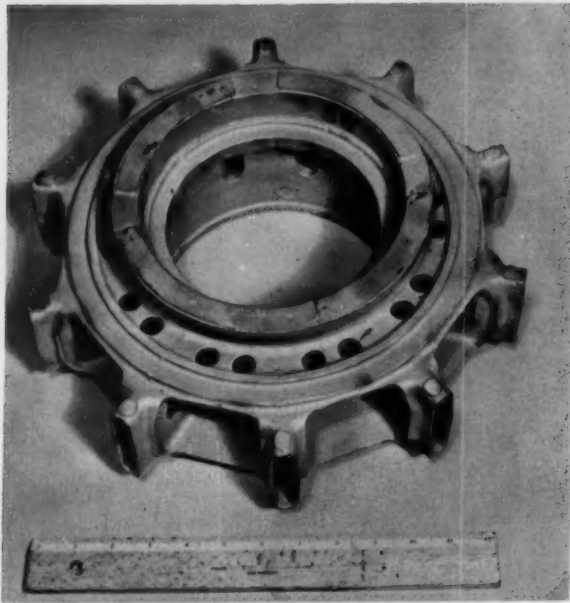


Fig. 5 — Casting produced from wax pattern made in a water dispersable sand mold.

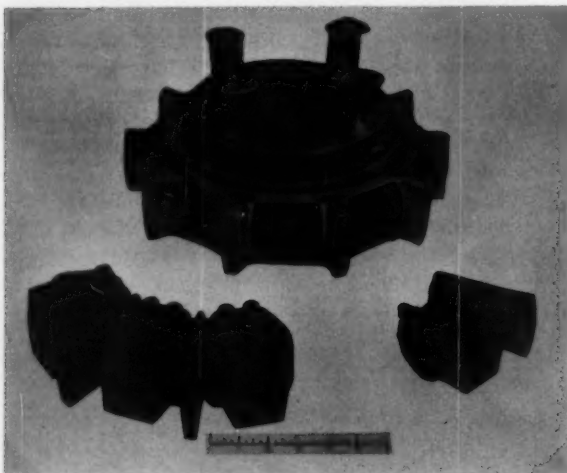


Fig. 6 — Wax pattern made from sand core assembly.

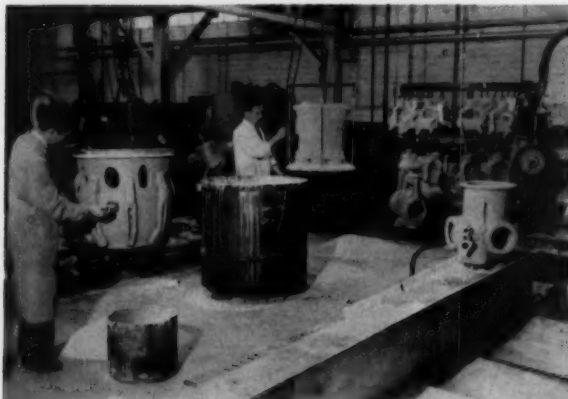


Fig. 7 — View of investment shell molding department.

carboxymethyl cellulose and sodium carbonate to make it water dispersible was developed. It was, therefore, possible to make wax patterns of virtually any size, the ultimate accuracy depending upon the skill of the patternmaker and the operator assembling the cores and molds.

A typical mix of water-dispersible sand is:

Material	Per Cent
Redhill 'H' sand*	91½
Zircon flour	1
Sodium carbonate	2½
Sodium carboxymethyl cellulose	5
Sodium silicate	8

\*Mechanical analysis:

BSS sieve	% retained
100	10-15
150	25-35
200	25-35
Pass 200	15-20

This method of making a wax pattern was the result of having a problem to be overcome, but the development opened up a commercial market for the supply of alloy steel castings which are large and heavy but thin.

#### Semi-Permanent Dies

While discussing temporary means of obtaining quick wax patterns for trials, it is worth mentioning at this point that on many occasions normal CO<sub>2</sub> bonded sand molds or plaster dies have been made from wood patterns and used as semi-permanent dies for wax injection. This is a quick method of obtaining wax patterns for normal investing where the component is solid or has simple internal coring.

In handling such large wax patterns, it is not usual to make a solid investment mold from both the viewpoints of both weight and economy. It is preferable to build up a shell of investment by alternate dipping in a bonding solution and dusting with the finely divided refractory until five or six coats have been applied to give a shell thickness of 1/8-1/4-in. (Fig. 7).

Many investment foundries now have a shell investment production line. It has the great advantage of overcoming the problems of bad packing associated with solid molds. These are vibrated to consolidate the investment around the pattern and result in bad packing on the underside of horizontal faces, while it uses less of the expensive mold refractories and binders. However, where components are relatively small with a small surface area/volume ratio conducive to close clustering on the runner system, the solid mold will be cheaper from the labor content aspect while consuming little more material.

Both solid and shell investments lend themselves to a high degree of mechanization and even near-automation. The investment casting process is probably the most universal inasmuch as almost any alloy can be successfully cast. The maximum weight is probably about 75 lb in the present state of the process, although castings have been made for development weighing well over 150 lb.

For general applications in commercial alloys, investment casting is not the best process. For example, it cannot compete in aluminum alloys with per-

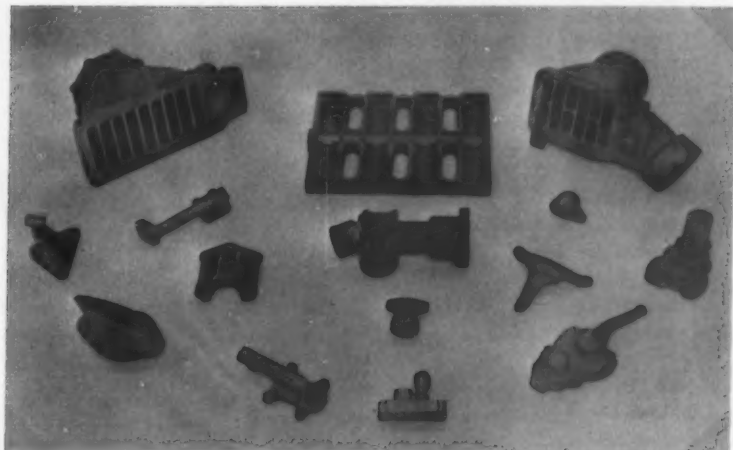
Fig. 8 — Steel castings made by CO<sub>2</sub> process.

Fig. 9 — Steel castings made by Shaw process.

manent mold castings for price, strength of material or accuracy. In the production of castings for the space age, investment casting is ideal for alloys which have to be cast in vacuum or a controlled atmosphere, and where the mold and crucible must not contain any siliceous material.

The *Investment Casting, Engineering and Design Manual* published by the American Investment Casting Institute gives comprehensive data on tolerances for investment castings. It offers  $\pm 0.005$  in./in. on functional areas and requests from  $\pm \frac{1}{64}$  in. on small dimensions to  $\pm \frac{1}{16}$  in. on dimensions of over 6 in. on nonfunctional areas. This partly confirms the original comment that precision casting is no more accurate than sand casting.

#### SHELL MOLDING, SHAW PROCESS AND THE CO<sub>2</sub> PROCESS

Three processes cater for a particular market requiring castings which lie between precision investment castings and normal sand castings.

The CO<sub>2</sub> process, the Shaw process and shell molding are illustrated respectively in Figs. 8-10. The essential difference between these processes is the method and materials used in making the molds.



Fig. 10 — Aluminum casting made by shell ('C') process.

CO<sub>2</sub> sands are invariably synthetic—a clay-free sand is mixed with 2-4 per cent of sodium silicate and rammed into the mold or core box in the usual manner. Before removing the pattern or core box CO<sub>2</sub> is blown through the sand, and a chemical reaction occurs which precipitates a silica gel from the sodium silicate thereby bonding the sand. The application of carbon dioxide takes a few seconds at a low pressure, i.e., 5-15 lb./in.<sup>2</sup> depending upon the size and shape of the mold or core. CO<sub>2</sub> is the preferred agent for hardening or solidifying the mold or cores, but the reaction can be accomplished by other agents in liquid or gaseous form.

They include ammonia, hydrochloric acid, methyl and ethyl alcohols, acetone, sulfur dioxide and nitrous oxide, but the use of these alternative materials involves certain hazards. After the gassing operation, the sand shape is immediately handleable and in most applications is ready for assembling and casting. The process can be used for casting most alloys. However, when casting nickel-base or other high temperature alloys, the silica sand is replaced by a finely divided refractory such as zircon.

The Shaw process uses similar materials to the investment technique, i.e., a refractory such as sillimanite with ethyl silicate-alcohol binder. The mixed slurry is poured over the pattern and fast, controlled gelation is affected by the addition of ammonium carbonate. The mold gels in a matter of seconds, and when stripped off the pattern it is ignited. When cold, the dried mold is assembled with cores made in the same manner.

#### Shell Molding

Shell molding, sometimes called the 'C' process uses clay-free sand mixed with about 3 per cent of urea or phenol formaldehyde cured under heat while in contact with the pattern. In operation an all-metal pattern or core box is maintained at a temperature around 500 F. The dry mixed sand and binder is dumped on to the hot pattern. The mixture starts to cure from the surface of the pattern, and a predetermined time cycle allows a given thickness of shell to be built up before inverting the pattern to allow the surplus sand mix to drop off. Curing is then completed by putting the pattern and shell in an oven at 500 F. The time cycle for making a shell is 60-75 s. The resultant shell mold looks like a large biscuit with a smooth faithful definition of the pattern on one side and a rough finish on the other, with a thickness of 1/8-1/4-in.

The author purposely groups these techniques together as a number of foundries operate the three processes in the same department. Careful analysis is needed to determine why one of the processes should not be used to produce all types of castings in these foundries but, nevertheless, each has a certain advantage over the others.

The CO<sub>2</sub> and the Shaw processes are similar inasmuch as they can both use loose wood patterns. Whereas the CO<sub>2</sub> process is cheaper, the Shaw process gives a better surface finish and will produce thinner castings by virtue of the fact that the mold, when assembled, can be raised to a high temperature.

Shell molding is the most economical where quantities warrant all metal pattern equipment being made, bearing in mind that the resins used in this process break down at a much lower temperature than either the sodium silicate of the CO<sub>2</sub> process or the ethyl silicate of the Shaw process. Therefore, with certain high temperature alloys and stainless steels, mold metal reaction occurs which gives a rough surface, or local contamination of the alloy, or both.

These three processes assemble molds and cores made from pattern equipment as in normal sand-foundry practice, therefore they exhibit dimensional accuracy of the same order. The author's opinion is that these three processes are used mainly by sand foundries which do not employ lost-wax methods, as a natural extension of foundry sand methods.

No skilled labor is required in operating these processes, the technical knowledge required being provided by the same type of person as controls an investment casting foundry. It is therefore considered advisable for a foundry management to investigate these methods which as yet do not fall into a definite category, because they open up a new market in steel castings which are neither sand nor precision.

Of course, CO<sub>2</sub> and shell molding are now established production processes used in aluminum, magnesium, bronze and iron foundries either as complete molds and cores or as cores for assembly into standard sand molds.

#### PLASTER MOLDING

Probably the best known form of plaster molding is the Antioch process, developed in the 1930's. Plaster of paris, plaster molding, gypsum molding and the Antioch process all use the same basic material, i.e., calcium sulfate.

In the research and development stages it was noted that, if the mold formed by the setting of the slurry were dehydrated and allowed to rehydrate without being disturbed, gypsum crystals would slowly reform throughout the mold mass as granules about the size of sand grains. These have sufficient intergranular strength at points of contact for the mass to retain its cohesion at all times and to acquire a high permeability to gases. The transformation does not take place on the surface of the mold because not enough water is present, so that the surface remains smooth while the remainder becomes granular and permeable.

The calcium sulfate is mixed with water to form a slurry which is poured over the pattern and sets solid in about 5 min. To have free water available for the hydration into granular form, it is advantageous to hydrate the green mold in an autoclave or an atmosphere of saturated steam. This can be done at about 15 lb/in.<sup>2</sup> in 6-8 hr for the average mold. The mold is allowed to stand at room temperature for about 14 hr, during which time the hemi-hydrate slowly rehydrates by combining with free water to become granular.

The mold is then dried at temperatures of about 450-475 F, and if the molds are allowed to reach oven temperature all the free water and most of the chemically combined water in the calcium sulfate is re-

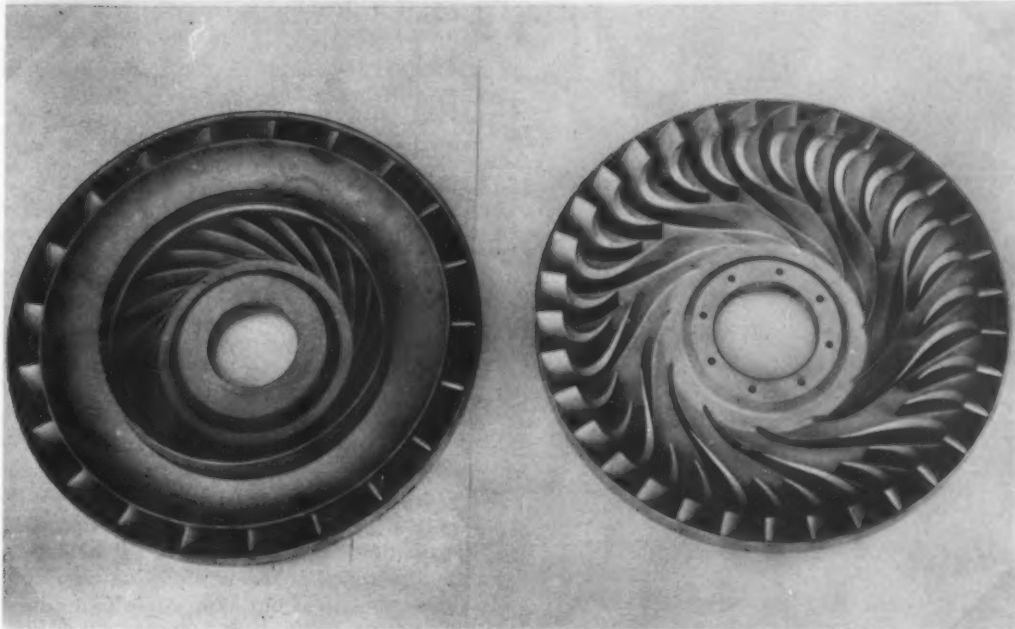


Fig. 11 — Aluminum castings by Antioch process.

moved. Up to 50 wt. per cent of finely divided sand can be added to the gypsum mix without interfering with the transformation of the mold structure into the permeable form.

During the process an expansion occurs which, if controlled, is in the order of one per cent or slightly less. This takes place while the mold is being dehydrated and rehydrated, and can be controlled by small additions of sodium silicate and Portland cement to give, in practice, between 0.1 and 0.25 per cent expansion.

The outstanding advantages of plaster molding are the surface finish and dimensional accuracy. The molding materials are, of course, more expensive than conventional sand casting materials, and where an ordinary sand casting will do the job it should always be used. In comparison with die casting, plaster molding is more versatile in the sizes and shapes which can be cast and, as the tooling costs are cheaper, the Antioch process will compete in price with die castings on medium quantity runs.

It does not overlap the investment casting or shell casting field to any great extent, and is restricted in the type of alloy which can be cast. For intricate shapes in aluminum-base alloys such as tyre molds, impellers, rotors, torque converters and wave guides, it is now well established (Fig. 11). One can expect a surface finish on aluminum and copper-base alloys by plaster molding of 30-40  $\mu$  in. (AA).

#### THE McCANNACORE PROCESS

An interesting aspect of the art of making castings in aluminum and magnesium is the possibility of obtaining small intricate unlined cast holes (Figs. 12 and 13). For magnesium castings, the McCannacore process allows complete freedom of design, thereby saving weight, material and costs.

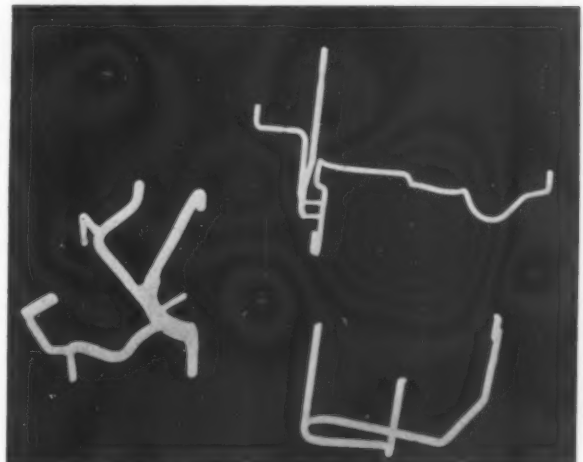


Fig. 12 — Intricate cores for McCannacore process.

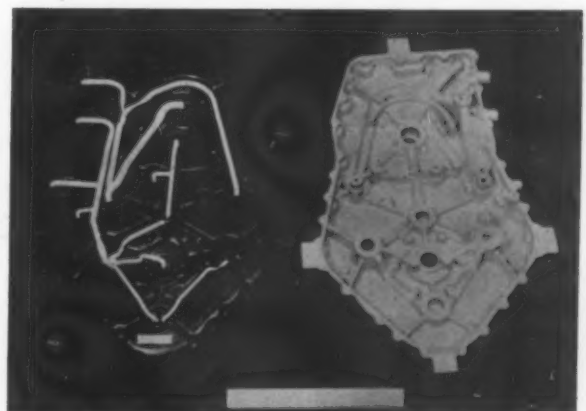


Fig. 13 — Intricate holes made by McCannacore process.



Fig. 14 — Iron die casting.

Briefly the process is to shape and bend heat resisting glass tubing to the desired configuration, and then to coat the assembly with a tungstic oxide wash, assemble in a sand mold and cast.

The completed casting is immersed in hydrofluoric acid to dissolve the glass tubing. To ensure that the passageway is properly cleaned out, the casting is x-rayed. As tungstic oxide is opaque to x-rays, its absence from the radiograph indicates that the glass has been completely dissolved.

A method for aluminum castings is the Dalton process which uses copper tubing bent to the required shape. The tube is then sheathed in fibreglass or braided steel wire. After casting, the copper is removed by reaction with nitric acid and the sheath pulled out, to leave a clean cast-in hole.

### DIE CASTING

In discussing this process, the great strides being made in this field must not be forgotten. Figures 14-18

show, respectively, die castings in iron, magnesium, aluminum (vacuum process), aluminum and bronze.

The American Die Casting Institute through its research foundation has completed the development of a flexible vacuum method for use in the die casting process. Its salient features are said to be:

- 1) Only the die cavity is evacuated.
- 2) Vacuum is maintained throughout the period of metal injection.
- 3) Pressures of 25 in. Hg, measured in the cavity, are consistently maintained without increasing cycle time.
- 4) The method can be conveniently adapted to provide vacuum feeding to the shot sleeve.

This is performed with a one hp pump supplying two average die casting machines, and with little modification to existing die equipment.

One of the greatest drawbacks to the use of pressure die castings in stressed applications has been the occluded and entrapped air in the casting which renders the component suspect from the viewpoint of reliable consistent physical properties, plus the restriction on the use of heat treatable alloys. One of the difficulties in having to heat treat a pressure die casting is that the temperature to which the casting has to be raised to obtain optimum physical properties causes the occluded air to expand and blister or even break through the surface of the casting. The new vacuum technique, however, will deserve a close examination to see how pressure die casting applications can be widened as more details of properties, etc., become available.

Slush casting is well known, being the method used to produce hollow castings where the internal finish or shape is not important. A domestic example is the aluminum teapot and kettle spout. An open metal die is filled with molten metal—the metal starts to solidify on the surface of the mold and, by experience, after a time lapse of a few seconds the mold is inverted and the still molten interior is allowed to run out. The section thickness is determined by the skill of the operator.

In recent months, an automated version of this has been announced, whereby the metal is injected into

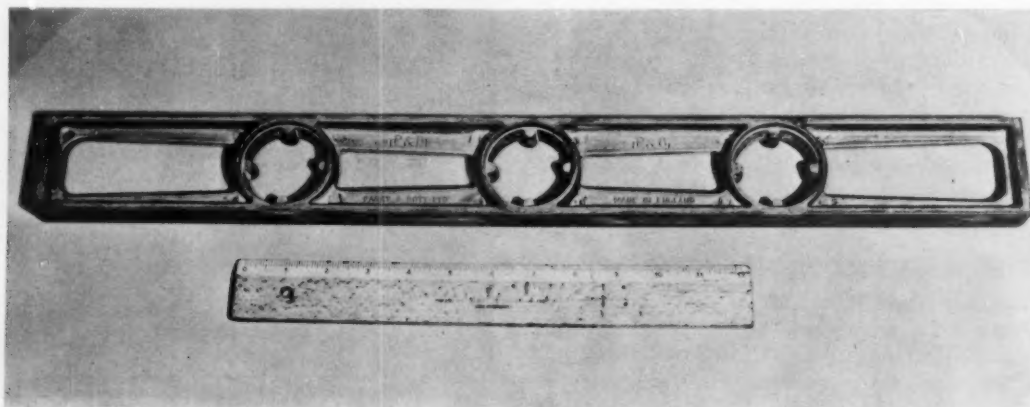


Fig. 15 — Magnesium pressure die casting.

the die and, after a predetermined time, the liquid interior is run off. Because this is all carried out on a controlled time cycle it is probable that this method may have engineering applications as it is said that consistent section thickness can be obtained.

### SAND CASTING

Having taken a brief look at these newer foundry techniques, it must not be forgotten that sand foundries with their semi-automatic and automatic plant still produce the cheapest castings. If the foundry maintains adequate controls and combines certain processes, such as CO<sub>2</sub> cores or shell cores in green sand molds, and even the use of the new oil-dispersable bentonites which permit green sand molding in the absence of water, there need be no fear of drastic competition from the newer processes.

The new processes, being expensive, must offer something special. The author hopes to prove it is not accuracy, but surface finish and section thickness, and it should not be beyond the ability of foundry technicians to introduce these two selling points into the sand foundry.

An example of a sand casting which comes within the definition of precision is shown in Fig. 19. This is the inner support for an early type of axial-flow jet engine in an acicular iron requiring minimum physical properties of 52,000 lb/in.<sup>2</sup> The two arms with feeders have a top and bottom wall thickness of 0.400 in. with side walls of 0.250 in. The remaining six arms have a general thickness of 0.150 in. The circular internal wall has a thickness of 0.125 in. The casting must, of course, be free from defects after examination by x-ray and dye penetrant.

Another example is the air intake casing for a turboprop engine, shown in Fig. 20. This is cast in a

magnesium-base alloy containing zirconium and rare-earth metals for high temperature application. The casting contains 43 cores, some of which are shown in Fig. 21. The lighter-colored cores are CO<sub>2</sub> process cores, and the darker ones are made with the traditional oil and cereal binder. Over 90 per cent of all coremaking in the author's magnesium foundry is by the CO<sub>2</sub> process.

Figure 22 shows an aluminum-base alloy containing 5 per cent copper, 1.5 per cent nickel and 0.2 per cent of zirconium. However, in certain higher temperature applications this component has to be fabricated in steel. This casing is shown in Fig. 23, which indicates the cast steel facings, etc., which are welded on to the sheet metal.

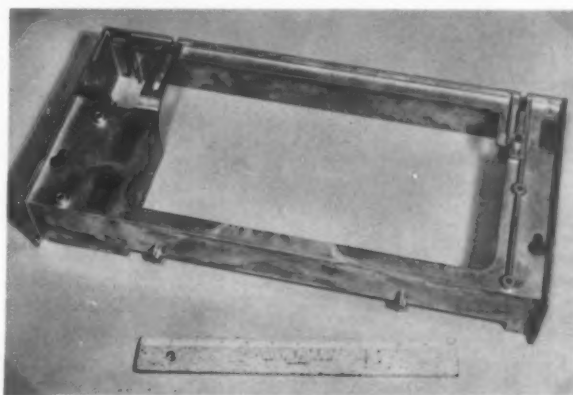


Fig. 17 — Aluminum pressure die casting.

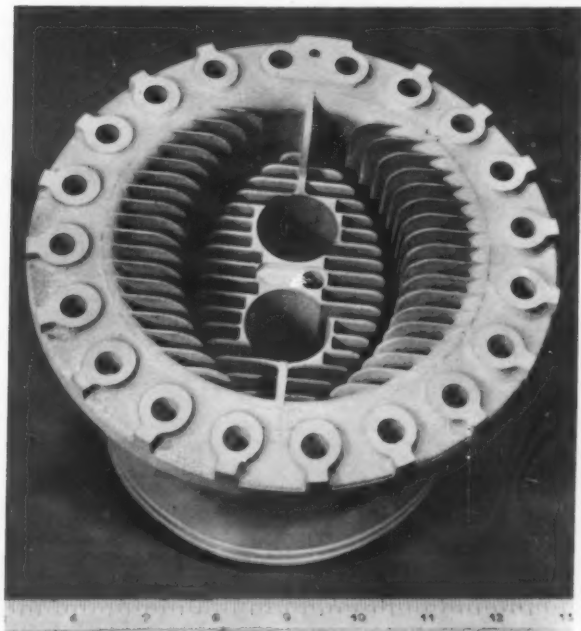


Fig. 16 — Aluminum vacuum die casting.

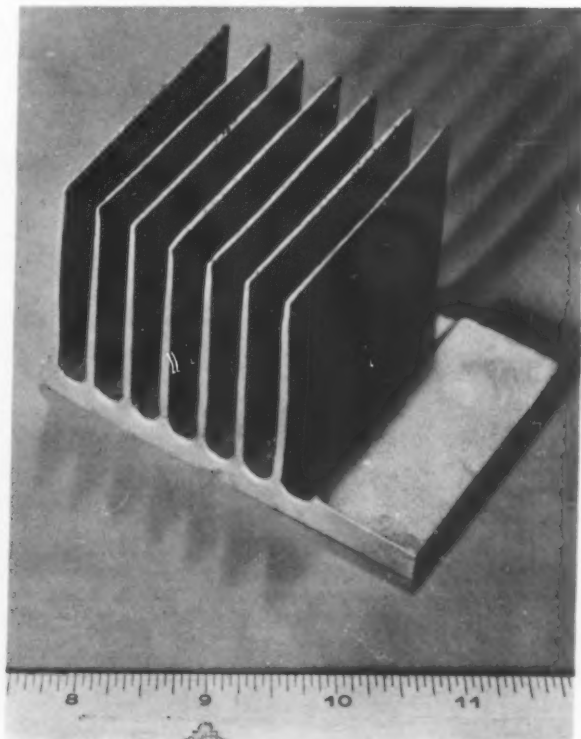


Fig. 18 — Bronze gravity die casting.

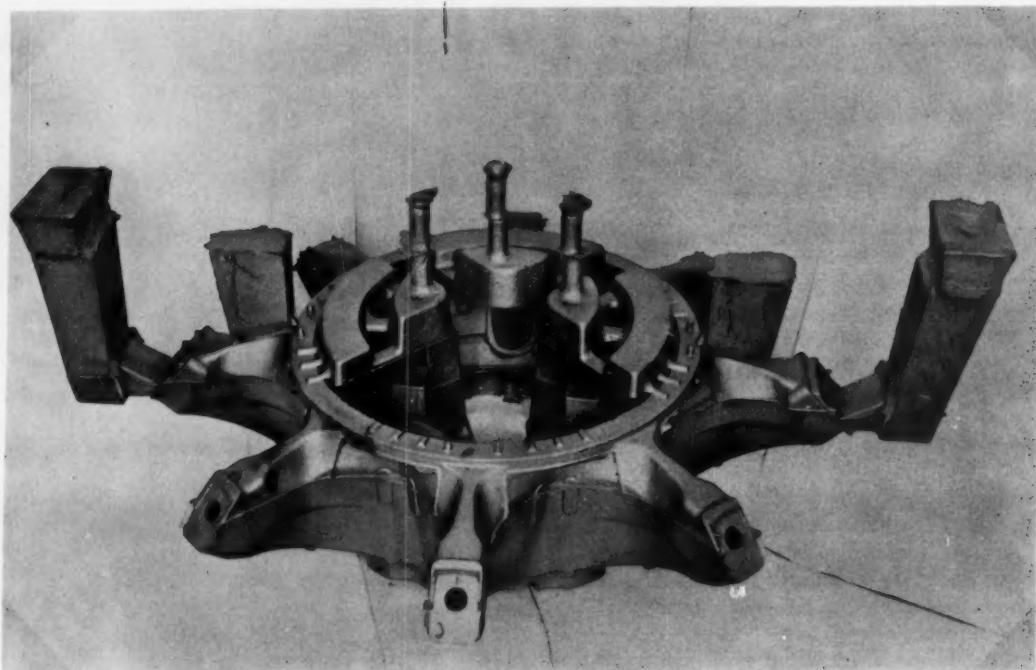


Fig. 19 — Support casing in iron.

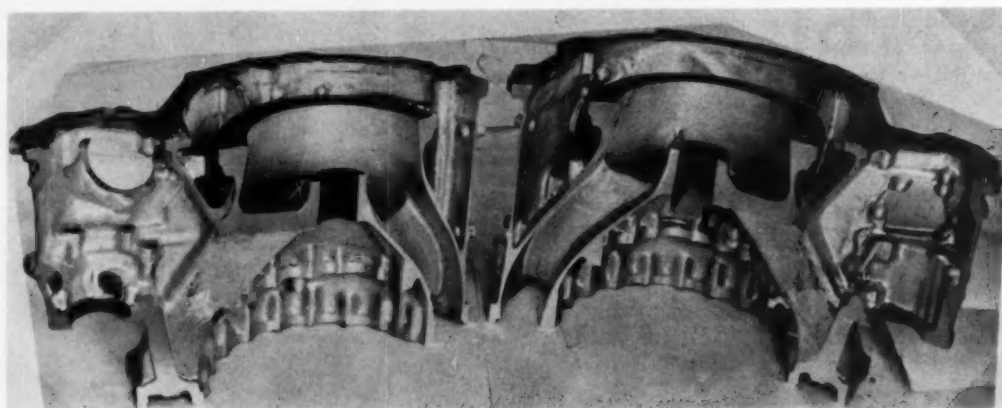


Fig. 20 — Air intake casing in magnesium.

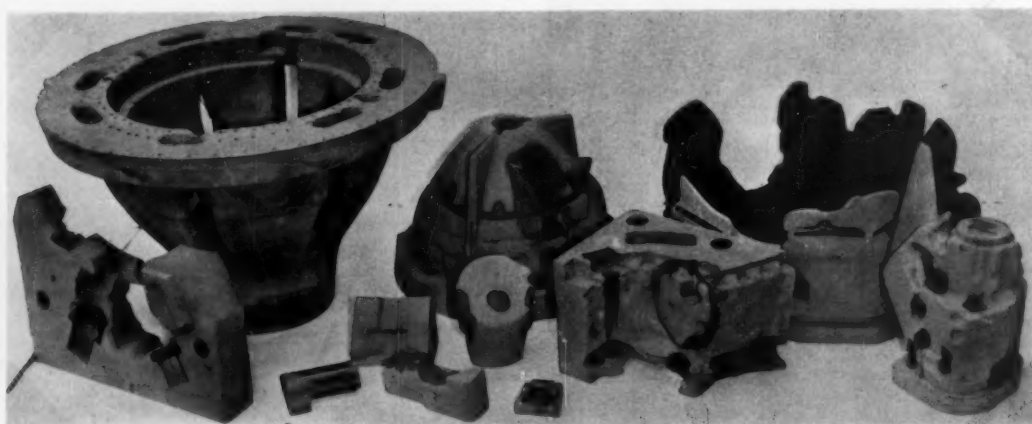


Fig. 21 — Some of the 43 cores for casting shown in Fig. 20.



Fig. 22 — Outlet casing in aluminum.

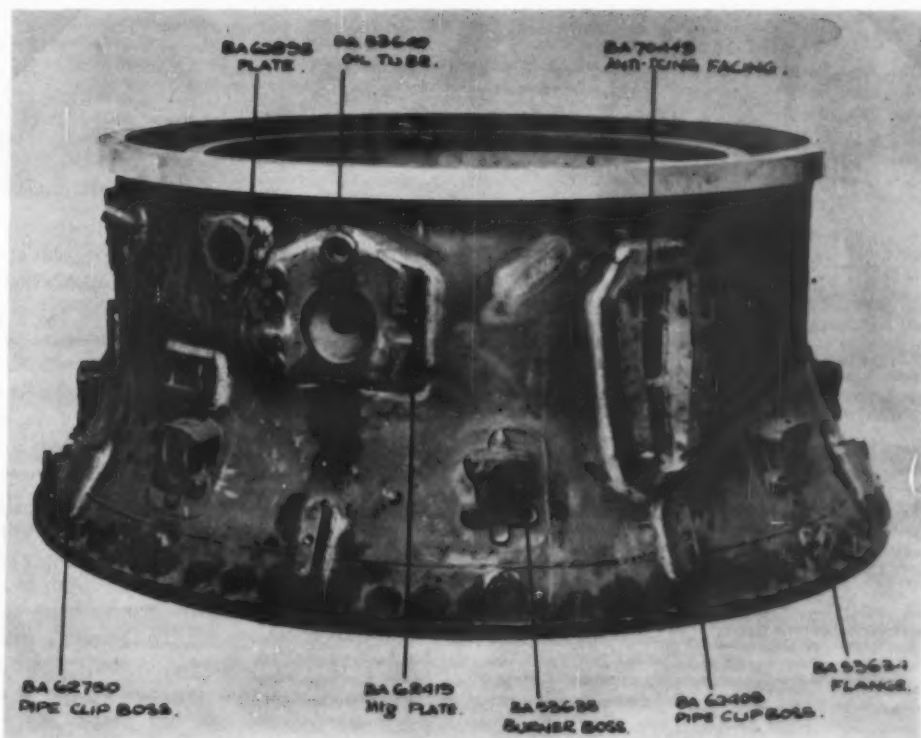


Fig. 23 — Outlet casing fabricated in steel with welded-on castings.

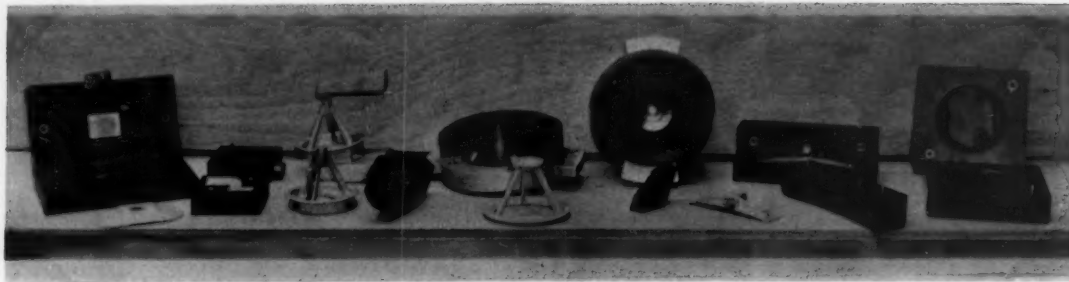


Fig. 24 — Epoxy resin dies.

### SURFACE FINISH

Almost every casting receives some form of surface finishing, even if only rough shot blasting to give a matt finish and camouflage defects. On the other hand many castings require an excellent finish for subsequent plating and polishing.

It is always desirable, therefore, to be prepared to go to some trouble in the foundry to obtain as good a finish as possible in the as-cast state to reduce subsequent finishing costs.

Some industries now specify surface finish in micro-inches. It may be quite foreign to the average foundryman to think of supplying castings to a surface roughness expressed in so many millionths of an inch, but this has to be accepted in the new age of founding. Numerical assessments of the average height of the irregularities constituting surface texture are expressed as the arithmetical average (AA). The British term for the same value is center-line average (CLA).

Taking some examples of castings by various processes some trials were made to find out what could reasonably be expected on as-cast surfaces, the results being as follows:

Process	$\mu$ in. (AA)	Base Alloys
Plaster mold	30-40	Aluminum and copper
Investment	40-50	Steel
Permanent mold	80	Aluminum
Shaw	80	Steel
Shell	100	Magnesium and aluminum
Sand	200-300	Aluminum
	150-300	Magnesium
	250-450	Iron

Naturally, the grain size of the refractory used makes a great difference to the as-cast finish, as also does the alloy to be cast, which, by mold metal reaction with the binders or refractories, can give a rough finish.

With an aluminum alloy containing 2 per cent silicon, 2 per cent copper, 0.1 per cent magnesium and 1 per cent nickel, the following maxima and minima on three castings were obtained.

Mold	$\mu$ in. (AA)
Natural sand (3% moisture)	300-500
Natural sand (Stove dried)	290-420
Silica sand (CO <sub>2</sub> bonded)	150-320
Silica sand (Fine grain, bonded with oil-dispersable bentonite)	160-185

The foregoing figures are not comprehensive and, this could be a subject for further investigation.

### DIMENSIONAL ACCURACY

From published literature some companies offer the following dimensional accuracy for the newer processes on linear dimensions.

Shell ('C')	$\pm$	0.010 in. up to 6 in. max.
	$\pm$	0.015 in. between 6 in. and 20 in.
Shaw	$\pm$	0.005 in. up to 3 in.
	plus $\pm$	0.0015 in./in. additional.
Plaster	$\pm$	0.003 in. up to 3 in.
	plus $\pm$	0.001 in./in. additional.
Investment	$\pm$	0.005 in./in.
	$\pm$	0.062 in. over 6 in.
CO <sub>2</sub>	$\pm$	0.010 in. up to 6 in.
	plus $\pm$	0.0015 in./in. additional.

It is not usual to find a sand casting varying more than 0.075 in. on the major aluminum and magnesium castings used in aero engines, but if this figure is converted over a 40 in. dimension, the tolerance is in the order of  $\pm 0.001$  in./in. which is better than tolerances offered by the newer processes.

### PATTERN AND DIE MAKING

In those sections of the industry making dies and patterns for use in the foundry, great strides are being made by the extended use of epoxy resins.

In the lost-wax process the epoxy resins have opened up a new field in competition with tin-bismuth alloy, as they can be cast from wood models. In the hands of a good patternmaker, the time to produce a given model and cast the epoxy die can be as little as one quarter of the time to cut the same die in steel in a toolroom (Fig. 24). Of course, in addition, drawing office time is completely eliminated as a patternmaker works from the component drawing.

An additional help in making epoxy dies from wood models is the introduction of accurate sheet wax having a self-adhesive backing (Fig. 25). When making a die having a general thickness of, say, 0.075 in. over a developed form which constitutes the bulk of the component, say, a pipe or casing, a model is made of the internal shape and core boxes are cast. Then, by wrapping the original model with self-adhesive wax sheet, a model is obtained of the exterior shape for casting the die, such features as

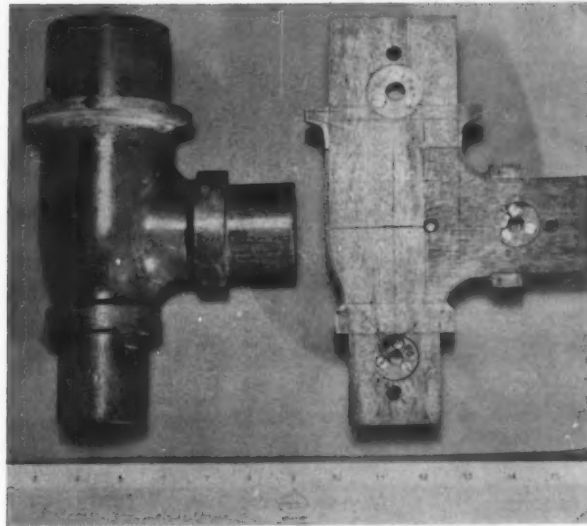


Fig. 25 — Use of sheet wax patternmaking.

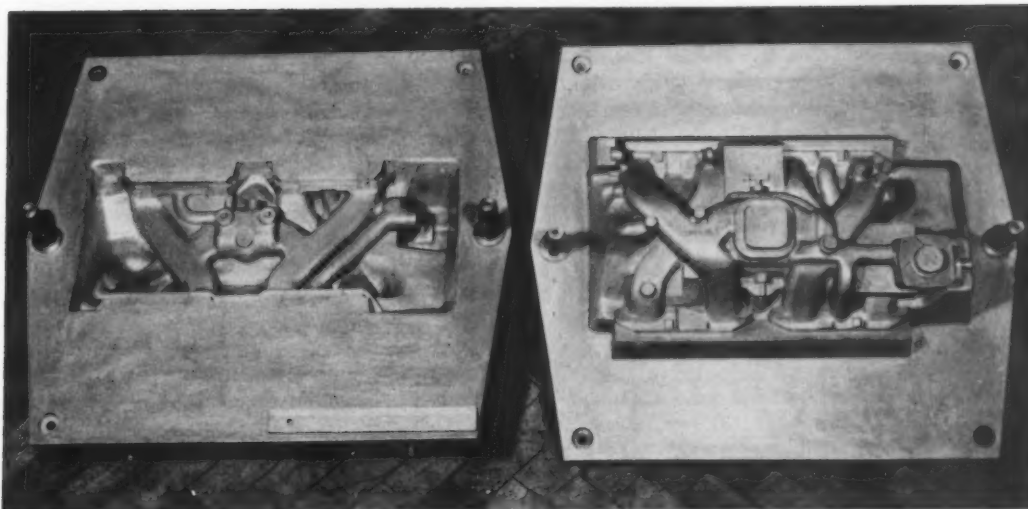


Fig. 26 — Fiberglass reinforced resin pattern.

exterior facings and bosses being added at the waxing-up stage. Similarly the patternmaker is increasingly using fiberglass-reinforced resin. Figure 26 shows an automobile induction manifold pattern made in aluminum powder filled epoxy resin reinforced with fiberglass.

### CONCLUSION

The introduction to this paper mentioned that enormous strides had been made in the foundry industry during the last decade. This development is hardly begun, since the space age requires the casting of metals such as molybdenum, tungsten, tantalum and niobium which will demand clinically clean foundries, with controlled atmospheres in areas where the castings are made, and high technological standards.

Nevertheless, precision as broadly defined already exists, particularly when one pauses to realize that castings are being made today that fulfill the following requirements:

- 1) Close tolerance with range specified. In some instances minimum dimensions are coupled with maximum weight.
- 2) Surface finish specified in micro-inches.
- 3) Pressure tightness in air pressure or hydraulic test.
- 4) Soundness by radiological examination.
- 5) Sub-surface soundness by penetrant dye test.
- 6) Physical properties by testing samples of each heat of metal.
- 7) Chemical analysis by sampling.

The author is conscious of the many omissions in this paper which go toward the making of precision castings such as inherent contraction characteristics of the metal, mold and core uniformity, mold pressures, gating and feeding practices, equipment and casting design. However, it is hoped that the claims made for new processes have been put in their correct perspective when related to sand castings, particularly from the viewpoint of precision.

# SOLIDIFICATION OF STEEL CASTINGS AND INGOTS

by M. C. Flemings, R. V. Barone, S. Z. Uram and H. F. Taylor

## ABSTRACT

This paper summarizes results of research conducted at Massachusetts Institute of Technology on solidification of high strength low alloy steel. The program was under sponsorship of Army Ordnance through Watertown Arsenal,<sup>1,2,3</sup> with its main emphasis on examining (1) different methods of obtaining directional solidification in cast steel and (2) effects of solidification variables on structure, segregation and properties of the cast steel.

A.I.S.I. 4330 and A.I.S.I. 4340 were studied. Electrolytic iron and other high purity charge materials were used to assure low sulfur content and freedom from impurities. Melting was by air induction. The majority of solidification experiments were on plate-like and cylindrical castings resembling ingots in shape. Solidification was controlled so the castings would freeze under a variety of thermal gradients. Control was obtained by using different molding materials and by using composite molds.

For example, plate castings were molded horizontally with an end riser in different types of molds including (1) zircon sand with a metal chill at the end of the plate, (2) silica sand chilled similarly, (3) silica sand without chill, (4) ethyl-silicate bonded mullite without chill, room temperature, (5) ethyl-silicate bonded mullite without chill, preheated to 1250 F (677 C) and (6) ethyl-silicate bonded mullite preheated to 1600 F (871 C).

The cylinder castings were also solidified under various thermal conditions, using mold materials similar to those that were used for the plates. They were cast (vertically) into different types of molds including (1) sand mold, (2) sand mold with bottom chill, (3) hot ethyl-silicate bonded mullite mold with bottom chill and (4) mold of exothermic moldable mixture with bottom chill. In the castings of item (4) above, essentially all heat was extracted through the chill and solidification under these conditions has been termed "unidirectional."

## INTRODUCTION

A major portion of this work was devoted specifically to the effect of solidification variables on microporosity. Microporosity (porosity so small as to be invisible to the naked eye except, perhaps, on a carefully polished surface) has been shown to be an

important factor limiting properties of cast nonferrous alloys,<sup>4,5</sup> cast steel<sup>6-9</sup> and other metals. Low gas contents and steep thermal gradients during freezing are necessary to completely eliminate microporosity; in certain nonferrous alloys gradients greater than several hundred degrees Fahr./in. are required, and these are obtained only quite near a chill (or metallic mold wall).<sup>4,5</sup>

Microporosity in steel castings and ingots, when present, can usually be discerned by careful metallography. However, a more sensitive, and usually simpler, technique is by radiography of a thin section cut from the casting or ingot. The thin section may be as much as 1/8-in. in thickness, or it may be much thinner; better resolution is obtained with thinner samples. It is possible, conveniently, to mill rather extensive sections to approximately 0.020 in. in thickness and radiograph this section; several recent studies on steel have been carried out using this type of "semi-microradiography."<sup>9,10</sup>

Small pieces can be reduced to the order of 0.005 in. or less in thickness; this type of thin section radiography is usually termed "microradiography." Trilatt<sup>11</sup> has reviewed the fundamental aspects of microradiography and described its application in many different types of investigation.

In this work, both semi-microradiography and microradiography were employed to determine location and amount of microporosity in castings produced. Factors other than microporosity were also examined and related to solidification behavior; these included grain size and type (columnar, equiaxed), dendrite spacing, inclusion size and distribution and macrosegregation. Mechanical properties (in the heat-treated condition) were obtained from the various castings produced. Details of experimental procedure not included herein may be found in earlier related papers and reports;<sup>1-3,12,13</sup> these publications also describe work on various solidification studies not reported here.

## FLAT PLATE CASTINGS

A series of test plates one in. thick was cast employing the mold design shown in Fig. 1. The distance from the end of the plate to the edge of the riser was slightly over 4 in. An exothermic sleeve was employed around the riser on all castings. Some castings were chilled as shown, and others were cast without a chill. Different types of mold materials were

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employed to obtain solidification under a variety of different thermal conditions (silica sand, zircon sand, ethyl-silicate bonded mullite preheated to several different temperatures).

#### Thermal Gradients and Microporosity

Thermocouples were placed at the centerline of each plate casting one, 2, 3 and 4 in. from the end of the plate, and cooling curves taken during solidification. From these curves thermal gradients along the centerline of the plates could be plotted, Fig. 2. These are average gradients in the liquid-solid (mushy) region during solidification; details of the calculation of this curve have been given earlier.<sup>1,12</sup>

In all plates produced, a positive thermal gradient existed along the centerline of the plate. Thus, solidification in all plates was directional from the plate extremity towards the riser. However, directional solidification is not sufficient to assure a completely sound casting in most metals. Adequate thermal gradients must also be present during solidification. These gradients must be steep enough to maintain open feed channels so liquid metal from the riser can flow easily through the interstices of the growing dendrites to accommodate solidification shrinkage.

In each of the plate castings examined, gradients were highest near the end of the plate farthest from the riser and decreased towards the riser. Gradients probably increased again immediately adjacent the riser,<sup>14</sup> but in most castings not enough thermocouples were used in this location to detect such a change. Thermal gradients near the end of the plate increased with increasing ability of the mold to extract heat—for example, gradients were greatest in the casting poured in the zircon sand mold, end chilled; they were least in the casting poured in an ethyl-silicate bonded mullite mold, heated to 1600 F (871 C).

To determine if gross porosity was present in any of the plates cast, they were first radiographed by ordinary nondestructive techniques; no porosity was evident. Slices were then cut from selected plates, ground to 1/8-in. and radiographed; again no porosity was discerned. Finally, the slices were ground to 0.020 in., re-radiographed, and microporosity was found in all castings examined. Results of three of these radiographs are sketched in Fig. 3. In the sand castings (castings a, b and c), microporosity was most severe in cases where thermal gradients during solidification were low. Some porosity was evident in each of these castings (chilled and unchilled) in areas where thermal gradients along the centerline fell below about 150-200 F/in. Surprisingly, porosity in one casting examined that had been produced in an ethyl-silicate bonded mullite mold appeared to be less than that in the unchilled sand casting. There is no apparent reason for this, and further work is necessary to confirm the observation.

The plate castings described above were poured of 4330 alloy. Test coupons were cut from the plates parallel to the chill edge, heat-treated to the 200,000 psi ultimate strength level and tested. Ultimate tensile strengths and yield strengths obtained were not dependent on bar location or on type of mold employed; however, elongation and reduction in area

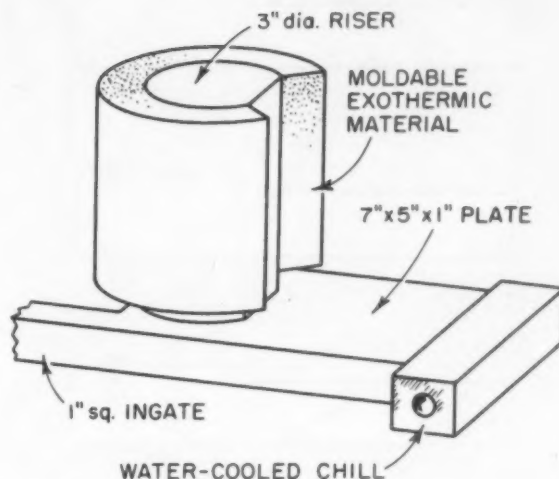


Fig. 1 — One in. plate pattern.

were sensitive to these parameters (particularly to bar location). Figure 4 is a typical plot of elongation versus distance from the plate edge for plates cast in sand molds. Elongation in all plates was lowest in the region of 3-4 in. from the riser; it was in this region that microporosity was greatest.

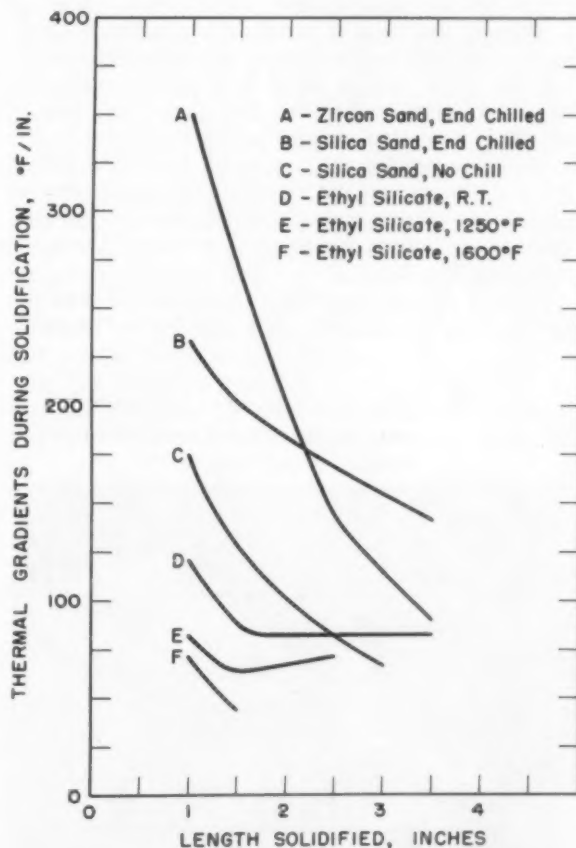


Fig. 2 — Average thermal gradients in the liquid-solid zone as a function of length of metal solidified for one in. thick plates (gradients measured between 2680 and 2610 F).

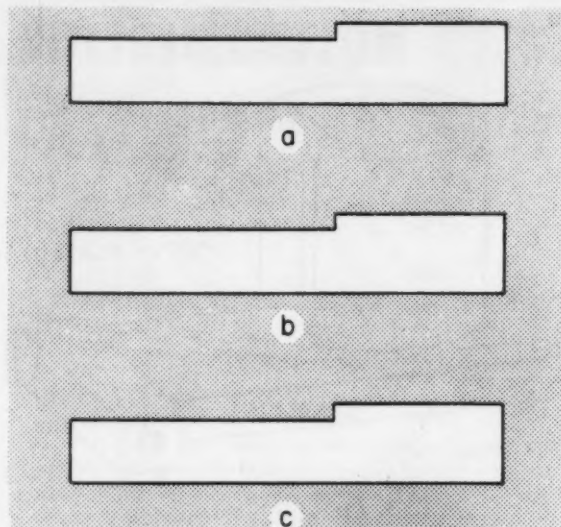


Fig. 3 — Semi-microradiographs of sections cut from cast one in. plates. (a) zircon sand, end chill, (b) silica sand, end chill, (c) silica sand, no chill.

#### Cooling Rate and Structure

The different molding materials described had effects on solidification of the test plates in addition to altering amount and distribution of microporosity. As would be expected, the cooling rate (during solidification) was quite different in different plates and in different locations of the same plate, Fig. 5. Cooling rates as high as 300 F/min were obtained one in. from the plate end in the most rapidly cooled casting (zircon sand, end-chilled plate); cooling rates of only 20 F were obtained at the same location in the ethyl-silicate bonded mullite mold, heated to 1600 F (871 C). The curves for average cooling rate during solidification show generally similar but not identical shape to the curves for thermal gradients along the centerline, Fig. 2.

Altering the cooling rate of a cast metal can alter its metallurgical structure in several ways. For exam-

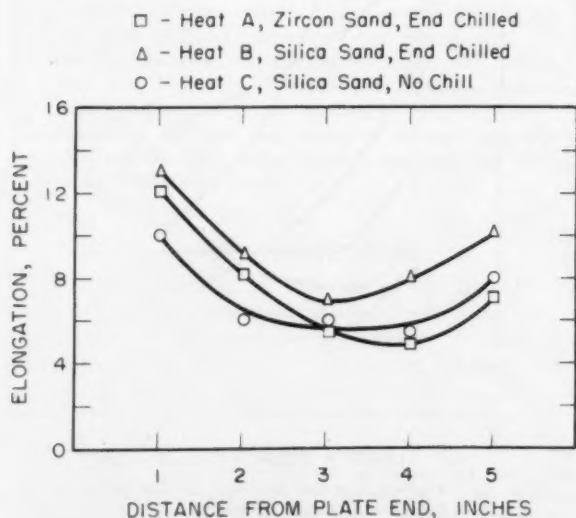


Fig. 4 — Elongation in one in. thick sand cast plate.

ple, increasing cooling rate can (1) alter the grain structure, (2) increase the fineness of the dendritic structure (decrease dendrite arm spacing) and (3) decrease the size of inclusions. In this work the macrostructures of the plate castings were not appreciably affected by the varying thermal conditions. All castings were composed largely of coarse columnar grains, the only major differences between the castings being that those that were end chilled exhibited a marked fine columnar zone, which extended a maximum of about one in. from the chill face of the casting towards the riser.

Microstructures were, however, greatly affected; fast cooling rates produced an extremely fine structure within the austenite dendrites; slower cooling produced a substantially coarser structure, Fig. 6. Inclusion size and distribution in the cast plates were also dependent on mold material and on location within the plate. Fast cooling rates resulted in fine inclusions, evenly distributed; slower cooling rates produced coarser, more agglomerated inclusions. Each of the above effects (in addition to microporosity) would be expected to have some influence on mechanical properties.

#### ADDITIONAL PLATE CASTING STUDIES

In order to examine further the occurrence of microporosity in plate castings, a series of plates of various lengths was poured; the plates were 1/2-in. thick and 5 in. wide and were end risered (Fig. 7). Plates were cast of 5, 3 and one in. lengths. One series of plates was chilled at the end opposite the riser, where-

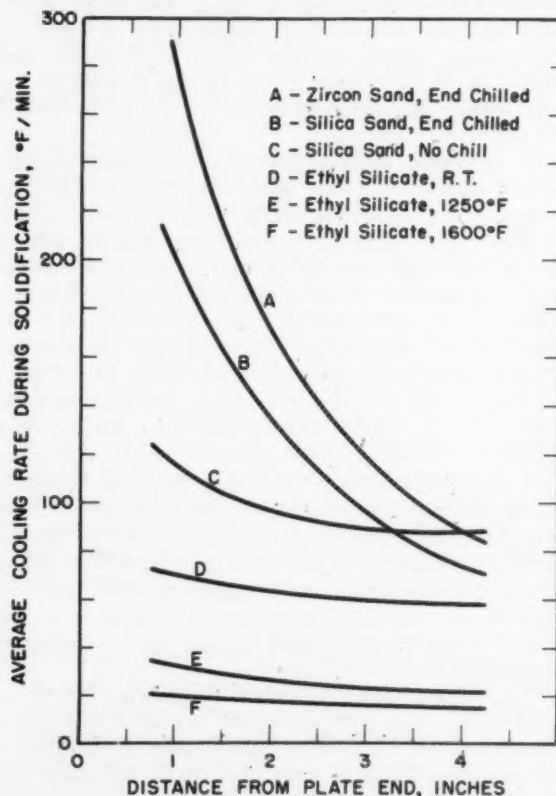


Fig. 5 — Average cooling rate during solidification from 2680 to 2610 F as a function of location in the cast plates.

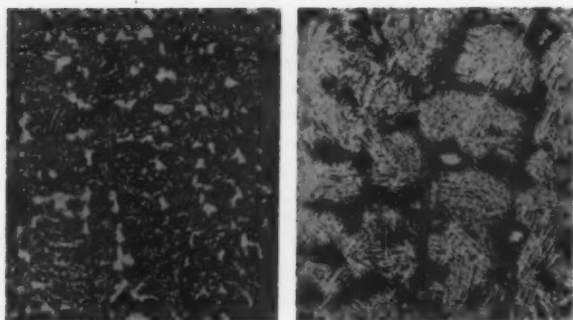


Fig. 6—Microstructures from as-cast one in. thick plates. *Left*—silica sand mold, end chilled. *Right*—ethyl-silicate mold, no chill. 50 $\times$ .

as a second comparison series was cast unchilled. The alloy studied was A.I.S.I. 4340.

All plates were apparently sound when examined by ordinary nondestructive radiography. This was expected from data on feeding distances in steel castings (except possibly for the unchilled 5 in. plate).<sup>15</sup> Nonetheless, microporosity was found to be present in all plates when examined by thin section radiography.

In this and subsequent portions of the investigation, microporosity was determined by radiographing sections approximately 0.006 in. thick (i.e., by microradiography). Several methods have been suggested for preparation of thin section for microradiography; the following procedure was employed. Specimens were mounted to a steel block with an epoxy resin mixture. They were ground to a thickness of about 0.010 in., removed and remounted on a special sample holder similar to that suggested by Sharpe.<sup>16</sup> After polishing one surface to a metallographic finish, the specimens were removed and the process repeated on the opposite surface; final sample thickness was approximately 0.006 in. X-raying was done using a standard x-ray diffraction unit.

Radiographs obtained were enlarged approximately 12 $\times$  and the amount of microporosity then evaluated by placing a grid on the enlarged radiograph and counting the number of squares in which micropores were found. The amount of microporosity was determined as:

$$\text{Amount} = \frac{\text{number of squares containing micropores} \times 100}{\text{total number of squares}}$$

This method of rating microporosity results in a per cent microporosity that is magnified with respect to true volume per cent. The magnification comes from the fact that the method, in effect, measures the relative area of microporosity, but does so on a specimen of finite thickness. Actual magnification probably depends somewhat on pore size and shape as well as on experimental technique. The procedure has the advantages of sensitivity and a yielding semi-quantitative data as to amount of porosity. Figure 8 illustrates a typical microradiograph of a fairly large amount of porosity (original magnification 50 $\times$ ); microradiographs showing three different levels of microporosity are in Fig. 9 (original magnification 12 $\times$ ).

As a result of examination of the amount of microporosity present along the lengths of the plates and

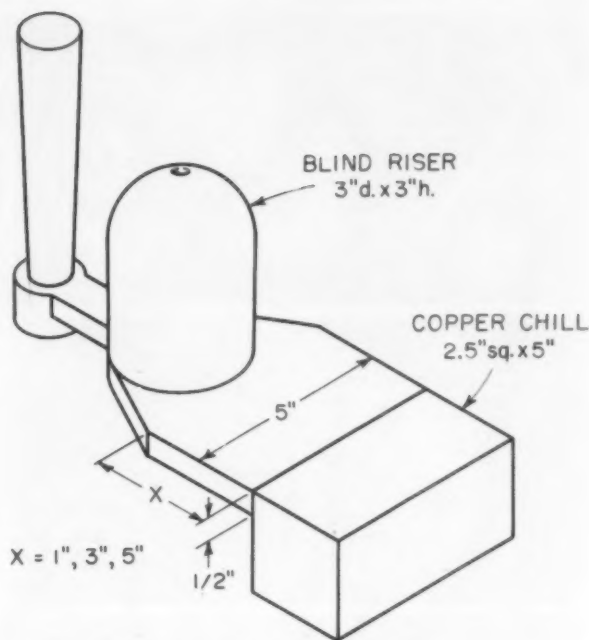


Fig. 7—Design of 1/2-in. thick plate casting.

correlation of this porosity with location in the plate and with mechanical properties, Figs. 10 and 11 were prepared; more complete results are presented in Table 1. Major conclusions from these data are (1) a correlation exists between microporosity and ductility in the plate castings and (2) tensile and yield strengths are relatively unaffected by microporosity (in amounts studied).

In all plates, chilled and unchilled, only small amounts of microporosity were present in the vicinity of the end of the plate opposite the riser. However, this porosity increased with increasing distance along the plate. Figure 10 presents data for two typical plates (3 in. long). In the chilled plate, microporosity was essentially zero near the plate end but increased to one per cent at about 2 in. from the end, and to 3 per cent near the riser.

In the unchilled plate, microporosity was also essentially zero near the end, but increased rapidly at locations closer to the riser. Elongation and reduction

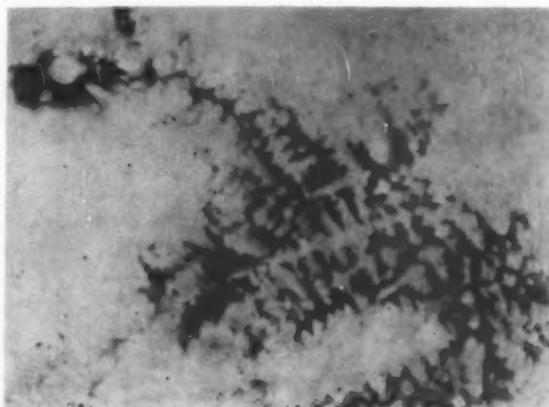


Fig. 8—Microradiograph showing interdendritic nature of microporosity. 50 $\times$ .

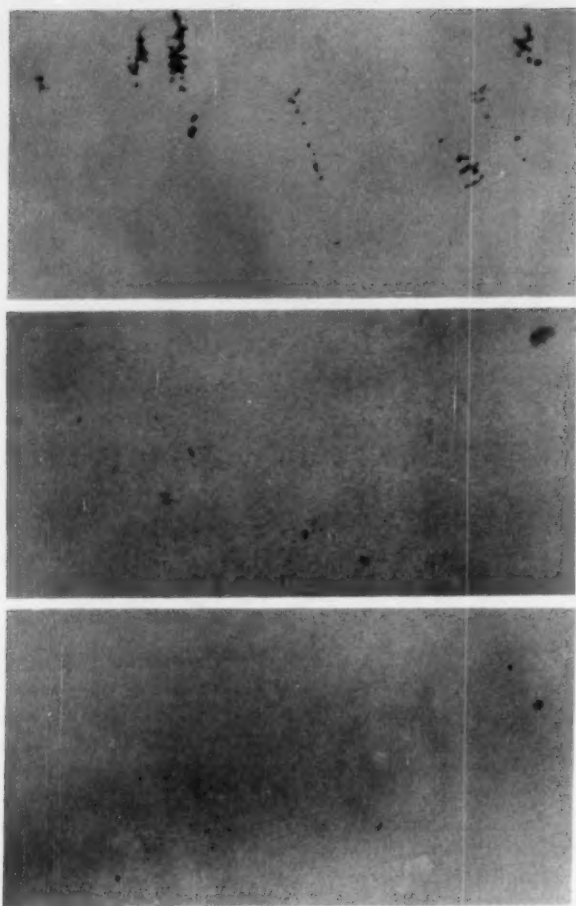
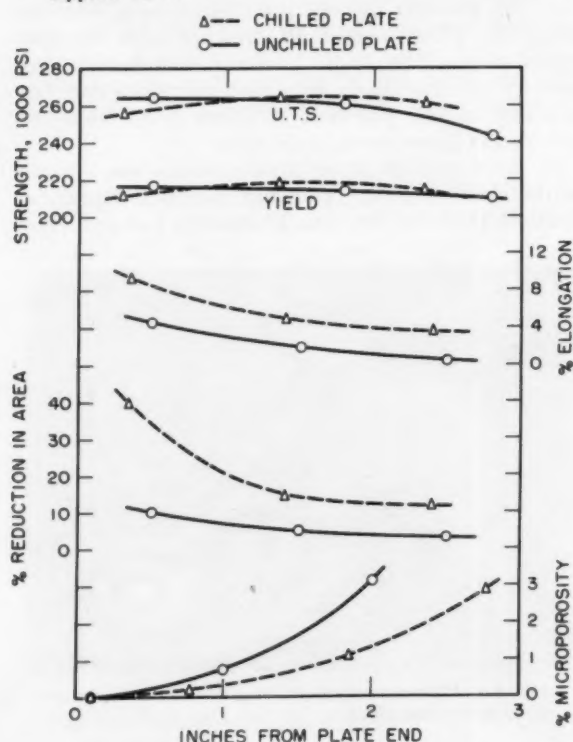


Fig. 9—Typical microradiographs showing microporosity (black areas). Top—3.50 per cent, center—0.85 per cent and bottom—0.20 per cent microporosity. Approx. 12 $\times$ .



in area generally decreased with increasing microporosity while tensile and yield strengths were relatively unaffected. Values of reduction in area as high as 40 per cent were obtained near the end chill.

Figure 11 summarizes microporosity data obtained from the 3 and 5 in. plates (chilled and unchilled); each of the points on this figure is the average of data from two to four different microradiographs. It should be remembered that per cent microporosity in Figs. 10 and 11 is a magnified quantity with respect to true volume per cent, due to the experimental method employed (point counting of microradiographs).

Figures 10 and 11 illustrate that it is extremely difficult to feed a steel casting to complete soundness. As thermal gradients are decreased from high values (several hundred degrees Fahr./in.) the amount of fine microporosity increases gradually. The type of microporosity that is detectable by microradiography is absent only in regions of a casting (1) close to a casting edge or (2) in the vicinity of a chill. Thermal gradients near a riser reduce porosity but do not eliminate it, as shown in the case of the 5 in. plate, Fig. 11. This fine microporosity, while probably of little significance in steel castings at low strength levels, is of major importance in determining ductility at the high strengths studied herein. There is some evidence that the porosity may influence properties of wrought steels as well.

#### Feeding to Soundness

It is of interest to compare results obtained from various investigations on the length of uniform sec-

Fig. 10—Bottom—left—Mechanical properties and microporosity in 3 in. plate castings.

Fig. 11—Below—Summary of microporosity data for 1/2-in. plate castings. Each point represents an average of 2 to 4 different castings.

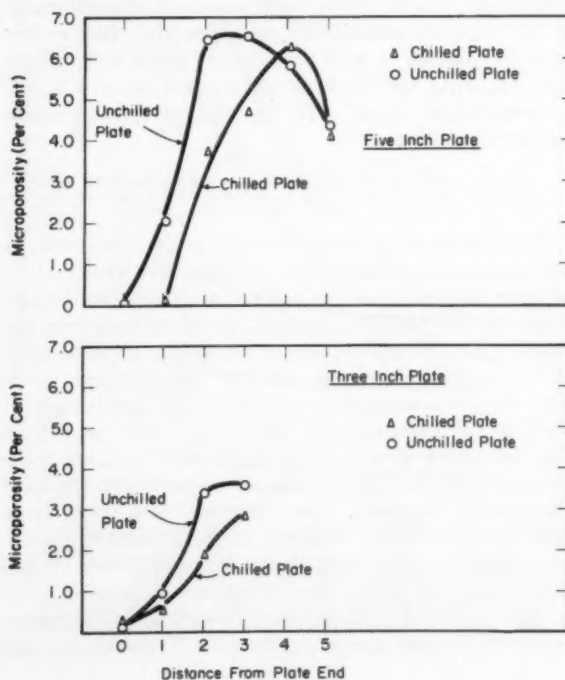


TABLE 1 — PROPERTIES OF 1/2-IN. THICK PLATE CASTINGS

Description	Plate Length, in.	Location (in. from plate end)	Tensile Str., psi	Yield Str. 0.2 per cent offset, psi	Elong., %	Red. in area, %	Microporosity, %
unchilled	1	0.5	262,000	216,000	5.7	15.6	0.90
chilled	1	0.5	264,000	216,000	7.9	27.0	0.10
unchilled	3	0.5	266,500	218,000	5.0	10.9	0.00
unchilled	3	1.5	262,000	216,000	2.1	5.5	0.71
unchilled	3	2.5	246,000	211,000	0.7	3.8	3.22
chilled	3	0.5	257,500	211,000	9.3	38.9	0.14
chilled	3	1.5	264,500	216,000	5.0	14.0	1.05
chilled	3	2.5	262,000	215,000	3.6	11.9	2.89
unchilled	5	0.5	265,000	216,000	2.1	3.8	1.05
unchilled	5	1.5	—	—	—	—	6.35
unchilled	5	2.5	242,000	213,000	0.7	3.3	3.54
unchilled	5	3.5	261,000	214,000	3.6	6.0	6.94
unchilled	5	4.5	258,000	216,000	1.4	4.4	4.33

tion castings that can be fed to soundness.<sup>9,15,17</sup> Table 2 lists data for chilled and unchilled plates, 1/2-in. thick. For castings of commercial quality (adequately sound to pass A.S.T.M. E-71, Class 2 standards), a plate 6 in. long can be produced with no chill and with one end riser; if a chill is employed at the extremity opposite the riser, an 8 in. long plate can be cast.

If apparent soundness is required when the plate is examined by nondestructive radiography, the maximum length that can be cast is somewhat shorter. If semi-microradiography is the inspection criterion the maximum plate length is again shorter, and if microradiography is the standard the maximum plate length is still shorter. The data in Table 2 have been assembled from widely different sources and apply to steels of slightly different compositions; however, the results almost certainly apply nearly quantitatively to 4330 or 4340 cast steel and illustrate how difficult it is to feed steel to complete soundness.

### CYLINDER CASTINGS

In order to study solidification in shapes that would more closely simulate heavy castings or ingots, a series of cylinders were cast, 4 in. in diameter at the base, with a top riser 5 in. in diameter, Fig. 12. The casting was 9 in. high end poured weight was approximately 40 lb. Castings were made in different type molds, including (1) sand, (2) sand with bottom chill, (3) hot ethyl-silicate bonded mullite with a bottom chill and (4) moldable exothermic material with a bottom chill.

When a casting was made in sand (with a top insulating cover of rice hulls) gross shrinkage was present, but was generally confined to the riser section, Fig. 13. The structure of the zone free of macroshrinkage (bottom half of the casting) was usually composed of a short zone of columnar crystallization with the remainder of the casting equiaxed. In castings poured at low temperatures, the columnar zone was absent (Fig. 14); in castings poured at higher temperatures the columnar zone was up to 1/2 the radius in length.

When a large metallic chill was placed on the bottom face of the mold cavity, the shrinkage cavity was moved upwards in the casting, and a zone of fine columnar crystals grew from the chill face 1.5 to 2 in. upwards; otherwise the chill had little effect on the

TABLE 2 — FEEDING DISTANCE IN END RISERED 1/2-IN. THICK PLATE CASTINGS

Standard for Soundness	Feeding Distance, in.		Reference
	Unchilled Plate	Plate Chilled on end	
ASTM E-71, Class 2	6	8	17
Radiographically sound (nondestructive, 1 1/2 percent definition)	4	6	15
Trace of porosity by semi-microradiography	2	3	9
Trace of porosity (approx. 1 per cent) by microradiography	1	1.5	This work

macrostructure (size of the equiaxed grains and length of the columnar grains on the side walls were not significantly altered).

To determine mechanical properties in the cylinder castings, coupons were cut from locations sketched

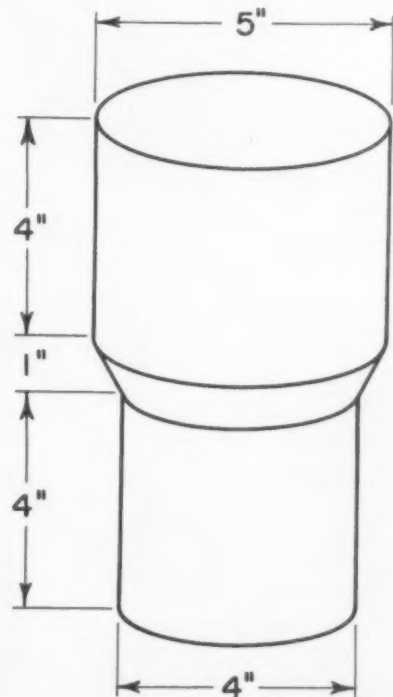


Fig. 12 — Nine in. high cylinder.

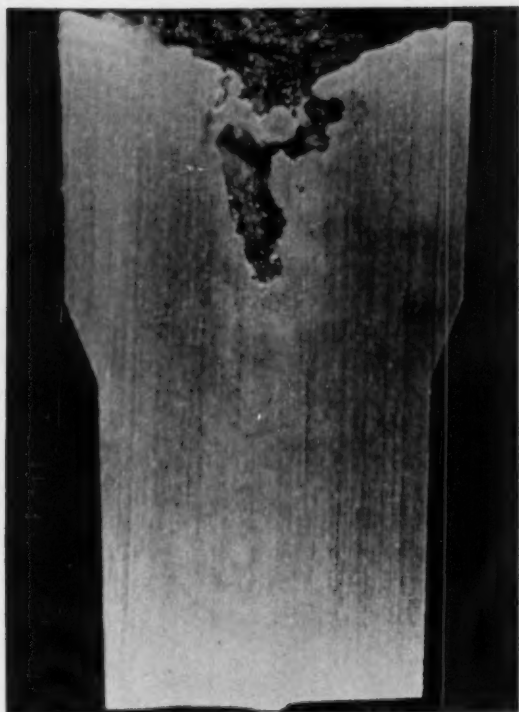


Fig. 13 — Section from 9 in. high cylinder casting.

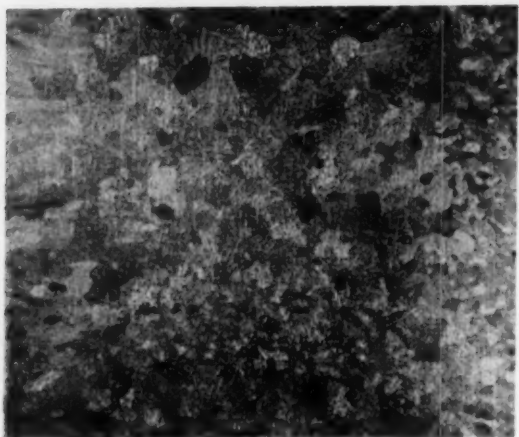


Fig. 14 — Macrostructure of sand cast 9 in. cylinder of section 4 in. wide x 4 in. high.

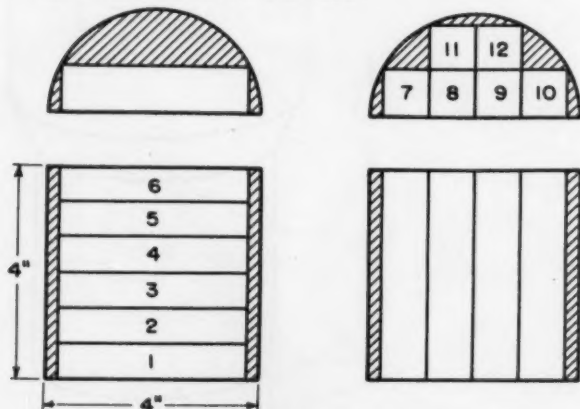


Fig. 15 — Test bar locations in 9 in. high cylinder casting.

in Fig. 15, heat-treated and machined into standard tensile specimens. Specimens for microradiography were also taken in the locations shown (along the centerline of the ingot). Ductility in sand cast cylinders was generally lower than that in the plates (Table 3), although in the bottom chilled cylinder ductility near the chill was quite high (Table 4). One reason for the generally low properties in cylinders was the presence of substantial microporosity (Table 5), but other factors related to the slower cooling of the sand cast ingot may also have been influential.

#### Unidirectional Solidification

In a first attempt to solidify the ingot under steeper temperature gradients, a hot ethyl-silicate bonded mold preheated to approximately 1850 F (1010 C) was substituted in place of the sand mold. A water cooled copper chill was used on the bottom face, and nonmetal producing exothermic material was placed on top of the riser. Extensive piping still occurred in the riser, and the casting was composed largely of equiaxed grains.

The mold design, illustrated in Fig. 16, was then constructed so as to achieve essentially unidirectional heat flow during solidification. Sleeves of preformed moldable exothermic material were set in a sand mold to form the side walls of the mold cavity, a water cooled chill formed the base and a layer of exothermic material placed on top of the casting (after pouring) formed the cope. A somewhat similar mold arrangement has been described.<sup>18</sup> The exothermic material employed burns at a temperature slightly in excess of the temperature at which steel solidifies. As a result, if any adequately thick layer of exother-

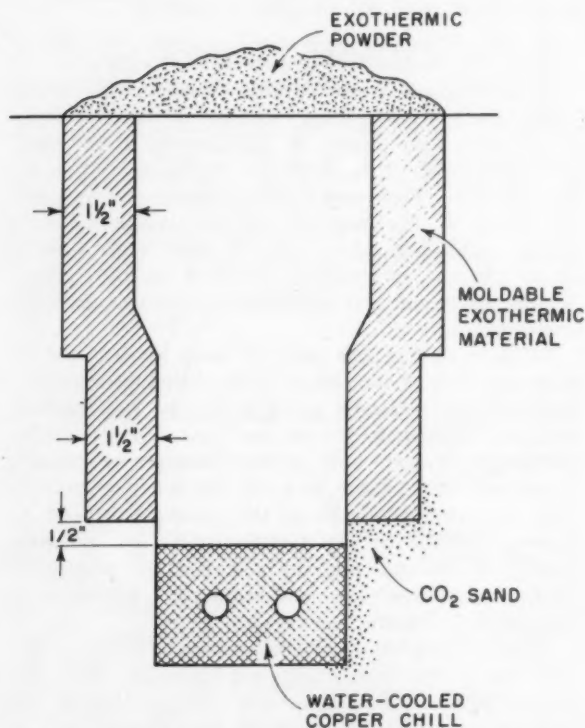


Fig. 16 — Left — top — Mold for unidirectionally solidified 9 in. high cylinder.

mic material is employed there can be no transfer of heat from the casting to the mold (except downward to the water cooled chill). There may, on the other hand, be some heat supplied from the mold walls to the casting.

In this casting, the sleeves were approximately 1½ in. thick. In early tests, they were pre-ignited and allowed to burn approximately 4 min before pouring the metal. In later tests the sleeves were not pre-ignited, and little difference was observed in macrostructures obtained. A total of five castings were poured which had structures similar to that of Fig. 17. They were columnar through most of their height, with the columnar grains extending vertically from the chill face upwards. In each of the castings the top inch or two contained equiaxed grains and some gross shrinkage. It appeared that the columnar grains might have been grown further had a greater amount of exothermic material been employed.

To determine if columnar grains could be grown to greater lengths, the ingot design sketched in Fig. 18 was constructed. The ingot was of uniform diameter (4 in.) and was 15 in. high. Moldable exothermic material was prefabricated into a series of sleeves of varying thicknesses; thicker sleeves were used at the top of the casting than at the bottom. The casting was bottom gated, and otherwise experimental procedure was similar to that for the 9 in. ingot. The macrostructure of the casting (Fig. 19) exhibited columnar grains 11 in. long out of a total possible 13 in. (total linear shrinkage in the casting was approximately 2 in. so the overall length of the final casting was only 13 in.).

#### Solidification Cooling Curves

Cooling curves were taken during solidification of two castings (a 9 in. cylinder and the 15 in. cylinder). Thermocouples were placed along the centerline of the castings at varying distances from the water cooled base plate. Three thermocouples were employed in the 9 in. cylinder and four in the 15 in. cylinder. In analyzing the thermal data obtained, the liquidus and solidus temperatures for the alloy were assumed to be 2700 F (1483 C) and 2600 F (1427 C), respectively. While these temperatures are not precise, relationships developed through their use would be affected only slightly by changes in the assumed temperatures.

In each of the castings studied, the advance of the fully solid interface was proportional to the square root of time. In the smaller casting, the position of the fully solid interface at any time corresponded to the equation:

$$D = 0.95 \sqrt{t} - 0.4 \quad (1)$$

where:

D = distance from chill to fully solid interface (in.).  
t = time (min).

In the larger casting the relationship was:

$$D = 1.15 \sqrt{t} - 0.1 \quad (2)$$

TABLE 3—TENSILE PROPERTIES OF SAND CAST 9 IN. HIGH CYLINDER CASTINGS

Casting No.	Location	Tensile Str., psi	Yield Str. 0.2 per cent offset, psi	Elong., %	Red. in area, %
A	1	258,000	211,000	4.3	10.9
	2	258,000	215,000	4.3	9.3
	3	254,000	215,000	2.1	4.4
	4	254,000	217,000	3.0	4.2
	5	264,000	219,000	5.0	5.6
	6	252,000	216,000	2.0	2.6
B	2	264,000	207,000	5.0	6.6
	4	263,000	206,000	2.9	3.3
	7	268,000	211,000	2.9	4.9
C-1	3	272,000	218,000	5.0	7.1
	5	273,000	223,000	4.3	6.0

TABLE 4—TENSILE PROPERTIES OF BOTTOM CHILLED SAND CAST 9 IN. HIGH CYLINDER CASTING

Casting No.	Location	Tensile Str., psi	Yield Str. 0.2 per cent offset, psi	Elong., %	Red. in area, %
C-2	1	270,000	218,000	10.7	27.0
	3	271,000	219,500	6.4	13.0
	5	272,000	224,000	3.6	5.5
	7	281,000	232,700	4.0	5.5

TABLE 5—MICROPOROSITY AND REDUCTION IN AREA OF SAND CAST 9 IN. HIGH CYLINDER CASTINGS

Casting	Location	Porosity, %	Red. in area, %
unchilled	2	1.3	7.1
unchilled	6	1.0	6.0
bottom chilled	1	0.4	27.0
bottom chilled	3	0.5	13.0
bottom chilled	5	0.1	5.5

The linear relationship with the square root of time, in agreement with theory,<sup>10</sup> indicates that heat flow in solidification of the castings was essentially unidirectional. Had significant heat in these castings been extracted through the sidewalls, a plot of distance solidified versus the square root of time would not have been linear but would have been of continually increasing slope. Experimental work using other metal systems has indicated this to be the case.<sup>5</sup>

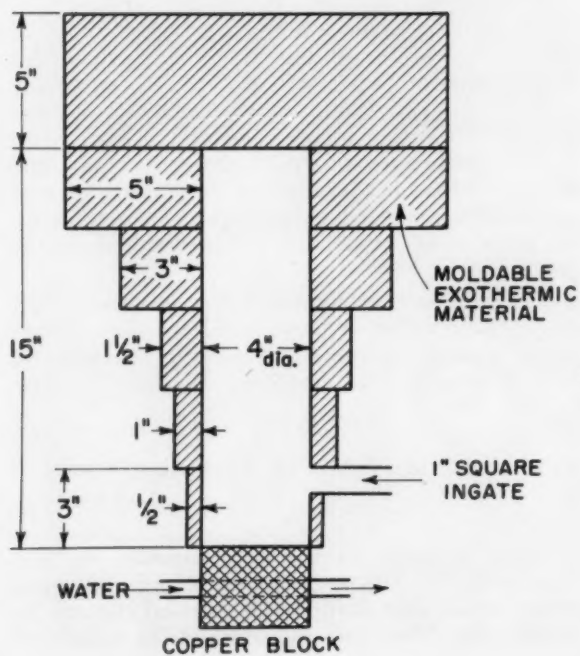
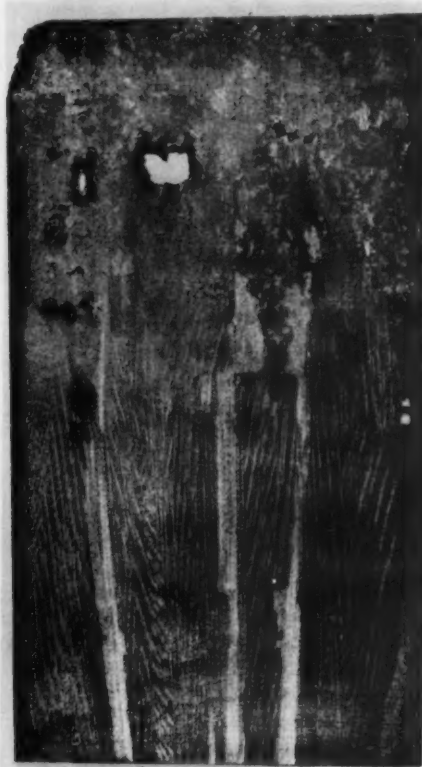
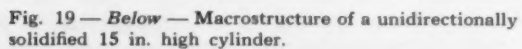
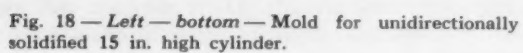
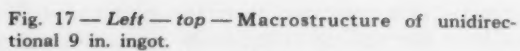
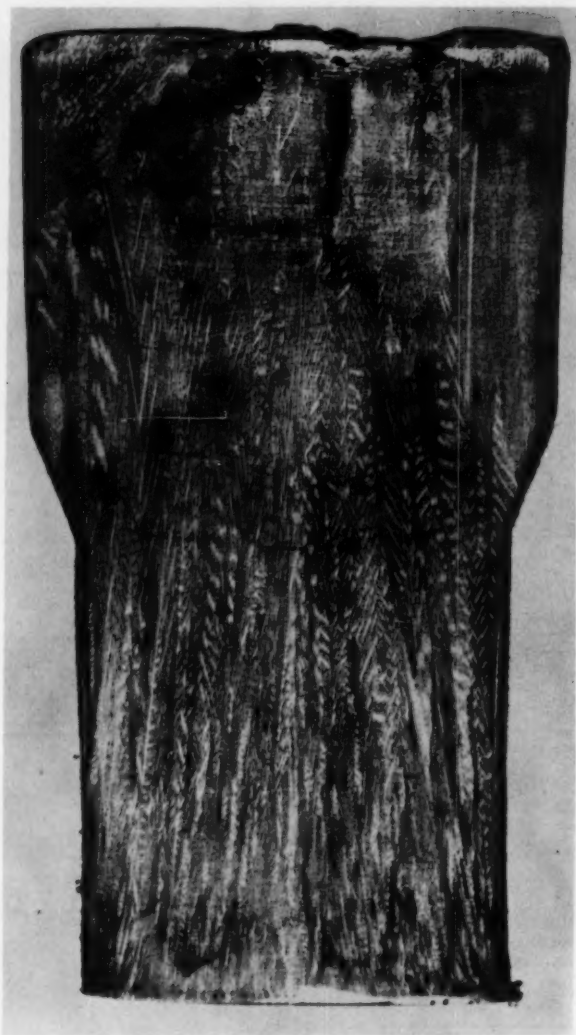
Solidification rates measured in this work are not greatly different from those found by other investigators studying solidification against flat walls of large steel ingots. For example, Marburg<sup>20</sup> found:

$$D = 1.20 \sqrt{t} - 0.90 \quad (3)$$

and Chipman and FonDersmith's equation<sup>21</sup> is:

$$D = 0.9 \sqrt{t} - 0.12 \quad (4)$$

Figure 20 shows, for the 15 in. cylinder, the positions of the liquidus and solidus isotherms at various times during solidification. The vertical distance between these curves gives the width of the liquid-solid



region at any time during freezing (or when a given amount  $X$  is frozen). This distance, sometimes termed the width of the mushy zone, is unusually small; for comparison, in ideal unidirectional solidification of many nonferrous alloys, the mushy zone is at least as long as the length of fully solidified metal.

To compare thermal data for the unidirectionally solidified cylinders with those given earlier for the plate castings, it is convenient to consider (1) cooling rate during solidification and (2) thermal gradients during solidification. These parameters were determined here in the same manner as they were for the plates (they may be obtained directly from Fig. 20).

A characteristic of unidirectional solidification is that while high cooling rates are obtained near the chill, these rates drop quickly (the square root of the reciprocal of cooling rate is approximately proportional to distance from the chill, Fig. 21). Cooling rates near the chill in the cylinder castings compare with those near the chill in the plate castings (Fig. 5). However, at distances of more than several inches from the chill, cooling rates in the cylinders are substantially lower than those in the plates.

On the other hand, thermal gradients during solidification are steeper in the cylinder castings than in the plate castings. Figure 22 shows the longitudinal gradients in the 15 in. cylinder casting. These are inversely proportional to the amount of metal solidified, and are significantly greater than the gradients in any of the plates, Fig. 2. It is these steep temperature gradients that result in columnar grain formation, and a narrow mushy zone during solidification.

#### Columnar Grain Structure

The width of the columnar grains in the unidirectionally solidified ingots increases with increasing distance from the chill. This has been observed for other metal systems, and is because grains more favorably oriented for growth gradually crowd out their neighbors during solidification. In dendritic growth of cubic metals, the preferred direction of columnar growth is the heat flow direction  $\langle 100 \rangle$ . If, in two adjacent columnar grains, the angle between their respective  $\langle 100 \rangle$  directions is divergent, the more favorably oriented grain will grow at the expense of the one less favorably oriented.<sup>22</sup> Table 6 lists average grain width at different distances from the chill for several ingots (as measured on a vertical section).

Columnar grains of the type grown herein possess an internal dendritic structure and so are often referred to as "columnar dendrites." The internal structure is apparent to some degree in the macrostructure of Fig. 17, and more clearly in the microstructure of Fig. 23. Ideally, a dendrite consists of one or several similarly oriented columnar stalks (or arms) with secondary arms emanating therefrom; tertiary arms may then emanate from these, etc.

Generally, slow solidification rates result in a coarse dendritic structure (relatively large distances between branches, and little or no formation of tertiary branches); higher solidification rates result in finer structures. It is now clear that the reason cooling rate and other variables affect the fineness of dendrite structures in an alloy such as the one con-

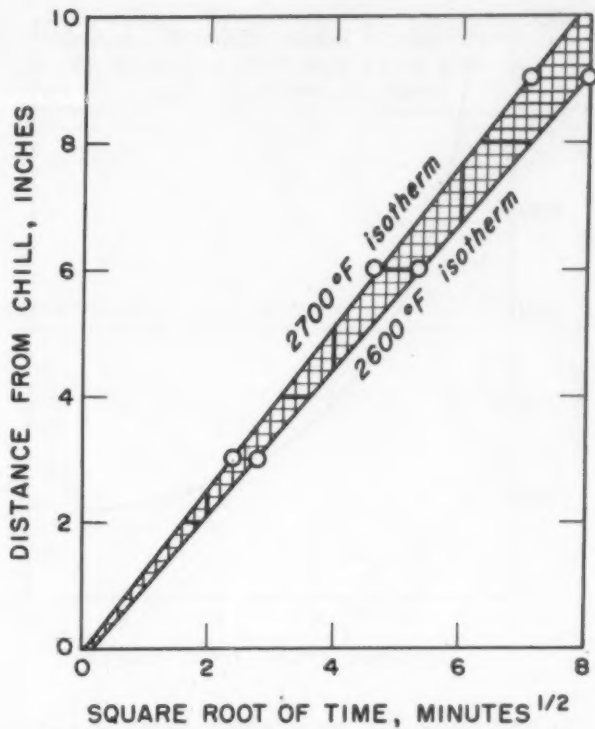


Fig. 20 — Distance to liquidus and solidus vs. sq rt of time for 15 in. cylinder.

sidered here, is because the variables affect the amount of solute that must be transported from the liquid-solid interface in a given time; i.e., the dendrites are solute dendrites.

One measure of the fineness of dendritic structure is the distance between branches of the dendrite. It

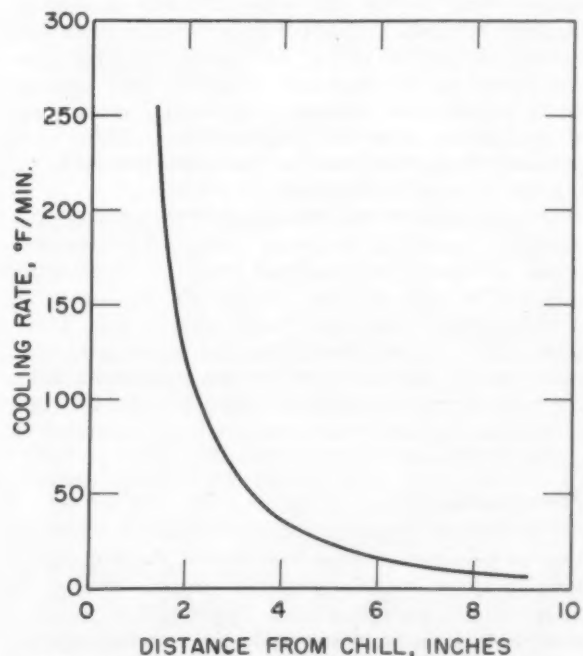
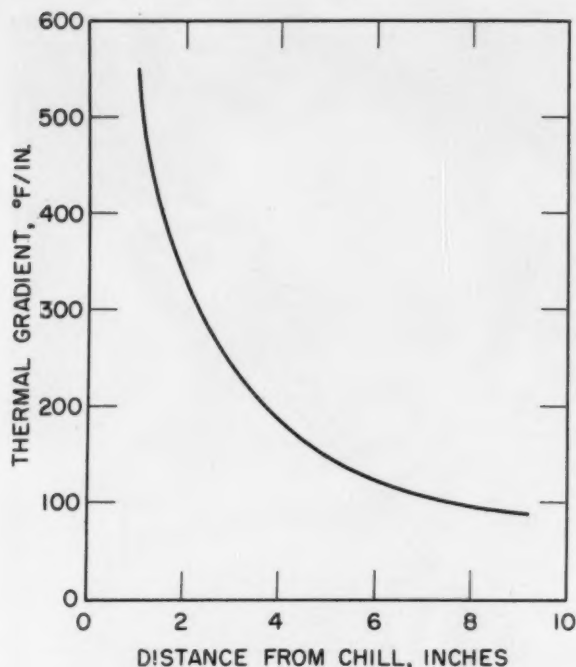


Fig. 21 — Average cooling rate during solidification as a function of locations in the cylinder for 15 in. cylinder (cooling rates measured between 2700 and 2600 F).



has been shown that under a wide variety of conditions this dendrite arm spacing is proportional to the square root of solidification time (or inversely proportional to the square root of average solidification rate).<sup>23,24</sup> Theoretical analysis has indicated this can be explained from fundamental mass transport considerations.<sup>24</sup>

In this work, spacings between both primary arms and secondary arms were measured on several castings. The spacing between primary arms is the average distance between the arms which appear as vertical lines in Fig. 23; secondary arm spacing is distance between horizontal lines. Results from one casting are plotted in Fig. 24; results for other castings were nearly identical. Dendrite arm spacing (both primary and secondary) is directly proportional to distance from the chill, and is therefore proportional to the reciprocal of the square root of freezing rate as would be expected.

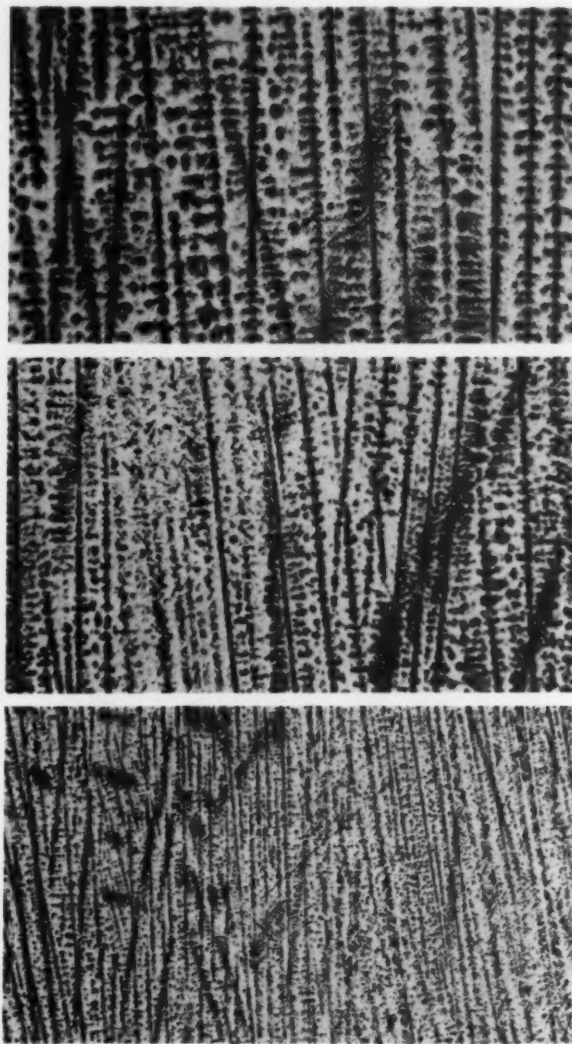
It is of interest that in addition to primary and secondary arms, the dendrites examined herein possessed a coarser, superimposed structure. This structure can be seen in Figs. 17 and 23; it consists of dendrite arms at an angle to the vertical axis. These arms, like those described above are regularly spaced; their spacing increases with increasing distance from the chill. Several possibilities might account for their formation, but these have not yet been examined in detail.

#### Macrosegregation

Previous investigations of unidirectional solidification of nonferrous alloys have shown that no significant positive macrosegregation occurs (except in alloys which expand during freezing).<sup>25,28</sup> In fact, analysis has shown that significant macrosegregation cannot result in most such cases if diffusion alone is the driving force.<sup>29</sup> The type of segregation which has been observed in unidirectional solidification of

Fig. 22 — *Left* — Average thermal gradients in the liquid-solid zone as a function of length of metal solidified for 15 in. high cylinder (gradients measured between 2700 and 2600 F).

Fig. 23 — *Below* — top — 3 in., center — 1¾-in. and bottom — ½-in. from chill. Dendrite arm spacing in a 9 in. unidirectional casting.



nonferrous ingots is inverse (increase in low melting constituents in the portion of the ingot to freeze first), resulting primarily from flow of solute rich liquid between growing dendrites to feed solidification shrinkage.

In the experimental work conducted essentially no positive macrosegregation was observed, except in the elements silicon and sulfur (Tables 7 and 8). Most of the remaining elements showed a slight tendency to segregate inversely; however, in most instances the amount of this inverse segregation barely exceeded analytical error. One exception was in the case of the analysis in the upper portion of the 15 in. ingot. Here carbon content was 0.34 per cent as compared with a nominal of 0.40 per cent, due to flow downwards of solute rich liquid. This portion of the ingot was quite porous.

In the case of silicon and sulfur, analyses invari-

ably showed higher contents at the top than the bottom. In one ingot 0.065 per cent sulfur was found near the top, while a similar analysis at the bottom showed only 0.008 per cent sulfur. It would appear that flotation of inclusions is the major factor responsible for the segregation. Tables 7 and 8 show a progressive but gradual increase in alloy element until near the top of the ingot; then, at the top, a discontinuous increase occurs. Also, the microstructures near the top of the ingot were generally considerably dirtier than those from the remainder of the ingot.

Contamination of the metal by the exothermic material was probably also a contributing factor to the segregation observed, at least in the case of silicon. Table 8 compares melt analyses of 2 heats with analyses from the castings poured in these heats. In general, slightly more silicon is present in the castings than was in the original metal; reaction of the metal with the molding material during pouring and/or solidification would readily account for this.

#### Inclusion Flotation

The ease of flotation of inclusions during freezing of a unidirectionally solidified ingot can be seen by considering Stoke's law:

$$u = \frac{gD^2(\rho_i - \rho_e)}{18\mu} \quad (5)$$

where

- $u$  = terminal settling velocity (cm/sec).
- $g$  = acceleration due to gravity (cm/sec<sup>2</sup>).
- $D$  = diameter (cm).
- $\rho_i$  = density of inclusion (gm/cm<sup>3</sup>).
- $\rho_e$  = density of liquid metal (gm/cm<sup>3</sup>).
- $\mu$  = viscosity (poise).

Assuming the viscosity of molten steel to be 0.025 poise, and density of inclusions to be about 4 gm/cm<sup>3</sup>, it can be shown that inclusions as small as 20 microns in diameter will float upwards at a rate of 0.6 in./min. This rate exceeds the rate of progress of the solidification front at only 0.55 in. from the chill. At distances greater than this from the chill, rate of progress of the solidification front is much slower, and even smaller inclusions can float in advance of the solidification front.

It is clear that small inclusions can float if they form above the liquidus temperature of the molten steel; here, no solid metal is present to prevent their movement. Inclusions which form below the liquidus temperature grow in the mushy zone (Fig. 20), and float or not depending on the extent to which dendrite arms have reached across interdendritic pools. It is probable that in unidirectional freezing some inclusions do float out of the mushy zone due to its narrow width.

#### Microporosity and Mechanical Properties

Each of the unidirectionally solidified castings were examined microscopically and microradiographically to determine amount and distribution of microporosity. In the case of the cylinders cast in sand molds, amount of porosity varied from zero per cent up to 2 per cent, depending on location in the casting and on chilling techniques.

TABLE 6—AVERAGE GRAIN WIDTH (IN IN.) AS A FUNCTION OF DISTANCE FROM THE CHILL FOR CYLINDER CASTINGS

Distance from chill, in.	9 in. high cylinder*	15 in. high cylinder
1.....	0.15.....	0.16
2.....	0.18.....	0.23
3.....	0.23.....	0.30
4.....	0.28.....	0.37
6.....	—.....	0.45
8.....	—.....	0.57

\*Data averaged from two cylinders.

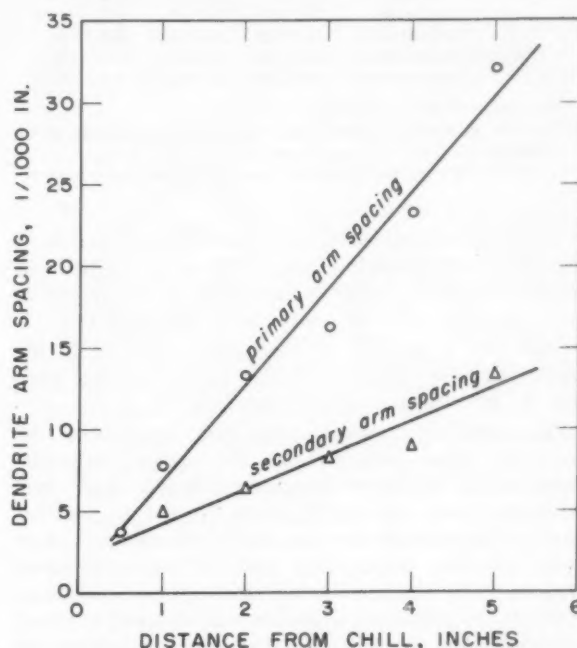


Fig. 24—Dendrite arm spacing as a function of location in a unidirectionally solidified cylinder from cylinder shown in Fig. 17.

TABLE 7—SEGREGATION DATA FROM A UNIDIRECTIONALLY SOLIDIFIED CASTING (15 IN. HIGH CYLINDER)

Location (Distance from chill, in.)	C	Mn	Si	Ni	Cr	Mo	P	S
1/4	0.40	0.79	0.25	1.85	0.89	0.25	0.002	0.013
4	0.40	0.78	0.38	1.91	0.90	0.24	0.002	0.011
8	0.43	0.80	0.25	1.91	0.90	0.24	0.002	0.010
12-13	0.34	0.70	0.76	1.83	0.85	0.23	0.009	0.028

TABLE 8—COMPARISON OF MELT ANALYSES WITH SAMPLES CUT FROM BOTTOM AND TOP OF UNIDIRECTIONALLY SOLIDIFIED CASTINGS

Casting	Location	Composition Element, %							
		C	Mn	Si	Ni	Cr	Mo	P	S
5	melt	0.46	0.80	0.31	1.83	0.83	0.30	0.012	0.012
	near chill	0.45	0.77	0.32	1.80	0.85	0.26	0.007	0.010
	near top	0.42	0.71	0.45	1.83	0.84	0.26	0.008	0.027
6	melt	0.45	0.92	0.36	1.77	0.91	0.23	0.008	0.031
	near chill	0.44	0.86	0.35	1.79	0.89	0.26	0.007	0.024
	near top	0.43	0.81	0.51	1.79	0.88	0.26	0.006	0.039

TABLE 9—TENSILE PROPERTIES OF UNIDIRECTIONALLY SOLIDIFIED 9 IN. HIGH CYLINDER CASTINGS

Cast- ing No.	Bar No.*	Orientation**	Tensile Str., psi	Yield Str., psi, 0.2 % offset	Elong., %	Red. in area, %
2	1	transverse	292,000	231,000	8.6	23.6
2	3	transverse	290,000	230,000	6.4	20.9
2	5	transverse	292,000	235,500	5.7	8.7
2	9	longitudinal	292,000	235,000	6.4	11.9
2	10	longitudinal	294,000	244,000	7.9	20.6
2	12	longitudinal	292,000	231,000	7.1	19.6
4	1	transverse	262,000	208,500	7.9	20.1
4	3	transverse	260,000	208,000	6.4	8.7
4	5	transverse	262,500	210,000	5.7	7.6
4	9	longitudinal	259,000	208,500	10.0	33.1
4	10	longitudinal	261,000	210,000	10.0	30.8
4	12	longitudinal	261,400	209,500	10.0	32.2

\*Bar locations shown in Fig. 15.

\*\*Transverse or longitudinal to direction of columnar grain growth.

In the unidirectionally solidified castings, results of the microradiographic examination were (1) little or no microporosity could be detected in the ingots at least up to 4 to 6 in. away from the chill but (2) in the top 1 to 2 in. of each ingot amount of porosity increased rapidly (in this location it was present in amounts up to 10 per cent, Fig. 19).

To date, mechanical properties have been determined from only two of the castings reported here, Table 9. In both castings, tensile and yield strengths were not significantly affected by orientation or position of the bar within the casting. However, ductility (elongation and reduction in area) was markedly affected. In both castings, optimum ductility in the transverse direction was obtained adjacent the chill; less ductility was obtained away from the chill. In one of the two castings transverse properties were not greatly different from properties taken longitudinally to the chill, but in the other casting ductility was markedly superior in the longitudinal direction.

Ductility (at a given strength level) was substantially higher in the unidirectionally solidified ingots than in the sand cast ingots. For example, reductions in area of the sand cast cylinders varied from 3 to 11 per cent, whereas in the unidirectionally solidified castings the range was 8 to 24 per cent. In the case of the sand cast cylinder that was bottom chilled, properties were higher, but except immediately adjacent the chill, were not as high as properties from the unidirectionally solidified plates. The high properties obtained in the unidirectionally solidified ingots are attributed to (1) reduction of microporosity, (2) improved chemical homogeneity on a micro- and macro-scale and (3) increased freedom from inclusions.

### SUMMARY AND CONCLUSIONS

A summary has been presented of work conducted at Massachusetts Institute of Technology over the last three years relating to solidification of low alloy steel castings and ingots. The main emphasis of the work has been on examining (1) different methods

of obtaining directional solidification in cast steel and (2) effects of solidification variables on structure, segregation and properties of cast steel. Flat plates and cylindrical castings weighing approximately 50 lb were cast using techniques to achieve varying degrees of directional solidification. Thermal gradients and cooling rates were measured during solidification and related to structure and properties.

Microporosity can be discerned in flat plates by careful microradiography even when solidification takes place under relatively steep thermal gradients (in excess of 150-200 F/in.). Ductility at high strength levels is markedly affected by presence of the microporosity.

Feeding distance in steel castings is a quantity that is strongly dependent on degree of soundness required. For example, in an unchilled 1/2-in. thick plate casting, feeding distance is 6 in. if a casting of ordinary commercial standards is to be produced; it is 4 in. if the casting must be radiographically sound, 2 in. if it must be essentially sound when examined by semi-microradiography and one in. if it must be essentially sound when examined by microradiography.

Microporosity is reduced in plates and cylinders by increasing thermal gradients during solidification. Techniques employed in this work were (1) use of chills and (2) use of chills plus an insulating molding material. Generally, techniques which result in steep thermal gradients during solidification also result in a fast cooling rate during solidification; as a result, they refine inclusions and decrease dendrite arm spacing (in addition to reducing microporosity). Techniques which promote solidification under steep thermal gradients increase ductility in cast steel as a result of the improved soundness and homogeneity.

### Thermal Gradients

Steepest thermal gradients measured in this study were obtained in cylinder castings using an arrangement designed to permit essentially unidirectional heat flow during solidification. A mold was employed with a water cooled base plate; sides and top of the mold were insulated with moldable exothermic material. By this technique, ingots were cast with columnar grains extending from the base plate nearly to the top of a 15 in. high ingot.

Microporosity was essentially absent in unidirectionally solidified cylinders, except at the topmost portions. For comparison, it was present in amounts up to 3 per cent in plates (porosity measured by point counting microradiographs), and in amounts the order of one per cent in cylinders solidified in sand molds. Dendrite arm spacing in the unidirectional ingots is inversely proportional to the square root of cooling rate; this spacing increases with increasing distance from the chill. Grain width also increases with increasing distance from the chill.

Unidirectionally solidified ingots are remarkably free of macrosegregation; the only significant segregation being an increase in sulfur and silicon at the top primarily due to flotation of inclusions during freezing.

Mechanical properties of unidirectionally solidified cylinders (particularly reduction in area and elongation) were markedly superior to those of cylinders cast in sand. For example, in one unidirectional ingot (in the heat treated condition) mechanical properties parallel to the columnar grains averaged approximately 290,000 psi ultimate tensile strength, 230,000 psi yield strength and 17 per cent reduction in area; properties were essentially the same transverse to the columnar grains. In another unidirectionally solidified ingot, mechanical properties parallel to the columnar grains averaged approximately 260,000 psi tensile strength, 209,000 psi yield strength and 31 per cent reduction in area; in the transverse direction, properties averaged 260,000 psi tensile strength, 209,000 psi yield strength and 9 per cent elongation. In a comparable ingot produced in a sand mold average properties obtained were, respectively, 275,000, 225,000 and 6 per cent.

The improvement in properties obtained by unidirectional solidification is attributed to (1) reduction and microporosity, (2) improved chemical homogeneity on a micro- and macro-scale and (3) increased freedom from inclusions. As a result of improved soundness and homogeneity, unidirectionally solidified ingots should prove to be more readily forgeable than conventional ingots. Also, wrought material produced from such ingots should be of unusually high quality (i.e., possess high transverse ductility, little or no chemical or other heterogeneities, etc.).

#### ACKNOWLEDGMENT

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# HORIZON REQUIREMENTS FOR CASTINGS

by S. R. Carpenter

## ABSTRACT

Current application of castings in Aerospace vehicles at the author's company are reviewed as a springboard to delineate additional casting requirements for design solutions ahead.

Power available for use in recent years is increasing at an exponential rate. During the period 1945-1965 power plant thrusts will increase from 3000 lb to 1,500,000 lb. The increase in power has created technological deficiencies in material requirements. Materials such as beryllium, titanium, stainless steel super alloys and the refractories are under intensive development to meet the needs. Parallel effort with castings is required to solve fabrication problems and conservation of high cost materials.

A study is presented showing cost benefits of castings in relation to forgings. Savings in material by use of castings can amount to as much as \$63,000 for 100 lb of finished parts in a material like columbium.

The future outlook for high quality castings is reviewed with favorable findings due to technical developments in fields applicable to foundry practices.

## INTRODUCTION

The aerospace industry is one of rapid change, dealing with complex systems. Capabilities are constantly being extended to the limit, and this dynamic action is needed in all industries supporting the product. Technology has advanced rapidly, and many newspaper reports of scientific achievement, routine as they seem, were imaginative only a decade earlier. As an example of how far and how fast progress has gone, the Aerospace Industries Association 1960 Forecast<sup>1</sup> cites technical advancement in these words:

"The decade 1960-1970 will see man's first personal entry into space. That this achievement postdates by only sixty years the birth of American aviation industry is indicative of the rate at which technical capability is advancing. The rate of development of new scientific concepts now is such that plans for the accommodation of future needs must be determined at the earliest possible date."

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Many tools are required for these future needs, and they are near. Some of the tools become available much sooner than others. The full complement for effective use is paced by a single one. Required structural materials in desired forms including castings is a pacing item for aerospace vehicles of the future.

## AEROSPACE CASTING USES REVIEW

Currently, one of the author's company's jet liners makes use of castings in accordance with the breakdown on Table 1. The spectrum of application ranges from nonstructural to primary structural applications.

TABLE 1 — AIR FRAME CASTINGS FOR JET LINER

Casting Alloy	Sand Cast		Investment Cast		Total	
	Designs	Castings	Designs	Castings	Designs	Castings
AZ91 Magnesium	27	38			27	38
ZK51 Magnesium	104	174			104	174
356 Aluminum	24	72	17	29	41	101
4130 Steel			1	1	1	1
304 Stainless Steel			3	6	3	6
347 Stainless Steel			9	66	9	66
410 Stainless Steel			11	35	11	35
17-4 Stainless Steel			4	34	4	34
AMS 5385			1	1	1	2
Total	155	284	46	173	201	457

There is flexibility in design of small complex shapes by the investment casting process. Figure 1 shows typical examples of investment castings with which there is a high degree of success in steel and aluminum alloys. Application studies of aircraft quality steel investment castings with a fair amount of complexity (hollow sections with 0.060 in. internal webs), and success is confined to about the 5 lb

Fig. 1 — Typical steel investment casting in a jet liner.



category. It is not intended to infer this size is maximum. Steel investment castings 30 in. long with a weight of 30 lb have been noted.

Experience with shell mold steel castings is limited to the type of Fig. 2. The round section is cored, and casting weight is 30 lb. Development was quite lengthy, and there was sporadic difficulties throughout the production run.

Nonferrous types of sand castings are represented in size and complexity by those of Figs. 3 and 4. There are notable examples of much larger nonferrous castings currently in use by other aircraft producers. Nevertheless, the castings for the company's applications have defects in various degrees requiring compensations in design by increasing section sizes.

#### CASTING DEFICIENCIES

An analysis of 1710 castings representing 19 designs showed a rejection rate of 183 parts, an overall average of 10.7 per cent. Per cent of rejections in various increments is found in Table 2.

Table 3 is an analysis by type of all the rejections reported in Table 2. Casting rejections, such as noted in Tables 2 and 3, are powerful influencing factors in selection of casting applications. Compensating fac-

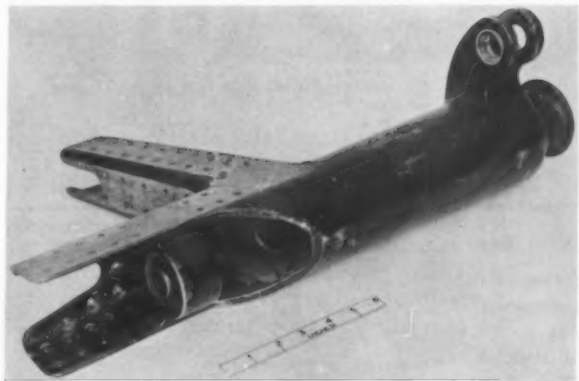
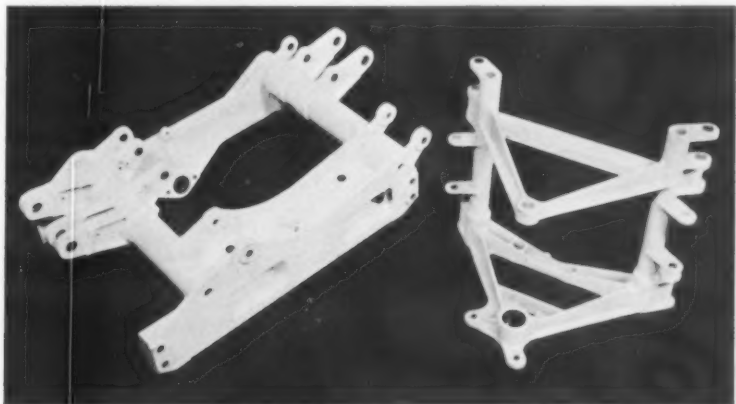


Fig. 2 — Shell mold type 410 steel casting in interceptor airplane.

TABLE 2 — INCREMENTAL REJECTIONS

No. of Castings	Rejections, %
86 .....	0
240 .....	0.1-5
803 .....	5.1-10
54 .....	10.1-15
331 .....	15.1-20
162 .....	20.1-25
34 .....	44

Fig. 3 — Typical flight control castings of AZ91 magnesium in a jet liner.



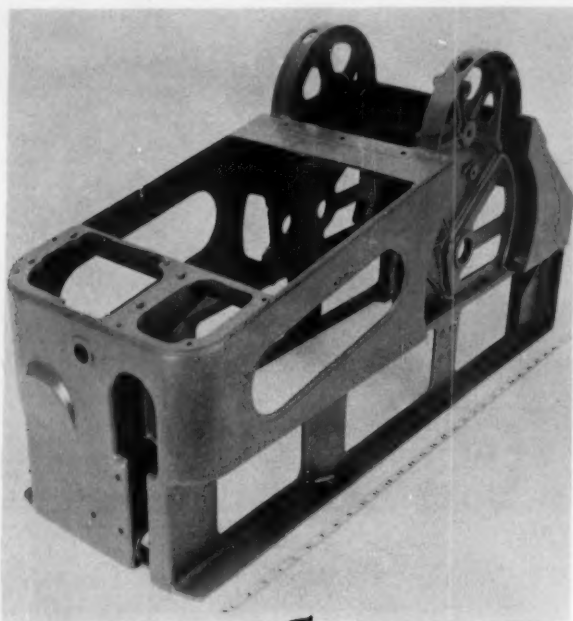


Fig. 4 — Pilot's control pedestal casting in AZ91 magnesium in a jet liner.

TABLE 3 — CASTING REJECT DISTRIBUTION

Defect Type	Radiographic Rejects, %
Shrink cavities .....	36.7
Segregation .....	26.5
Gas holes .....	9.4
Microshrink .....	7.7
Dross and inclusions .....	7.7
Cracks .....	2.5
Hot tears .....	2.5
Cold shut .....	1.7
Misruns .....	0.8
All others .....	4.5

tors of lower design allowables to account for casting defects in critical design applications rule out many castings. This is especially true of large castings in dense materials like steel, where lower design allowables to account for defects add weight in rapid fashion. It is an unfortunate circumstance because improvements in casting techniques would open the gates to wider casting acceptance than now enjoyed. The principle deterrents are — (1) weight penalties to compensate for casting defects and (2) defects affecting fatigue life.

#### ALTERNATE SOLUTIONS

The present status of castings forces companies into other design solutions. Figure 5 is an example of a 4340 machined steel forging with built in cost. It went the forging route because other methods like weldments and present casting techniques did not meet the company's design philosophy. The forging was machined to size in almost its entirety at a strength level of approximately 125,000 psi. Minor machining followed after final heat treatment of 200,000 psi. The rough forging weighed 52 lb. Machining operations generated 40 lb of chips to make a finished part weighing 12 lb. Approximately 12 hr was required for the machining operations, 8 hr of which consisted of pocket end milling.

The forging (Fig. 5) is an interesting study in pointing up two significant cost factors. (1) Large losses in material. The case at hand shows a 77 per cent material loss in the form of chips having only scrap value. A study of 28 other steel forgings confirmed similar losses. 383 lb of rough forgings yielded 87 lb of finished parts. Titanium forgings also have about the same yield. (2) The high cost of shaping to size a part without undue complexity in a material with a reasonable machinability index.

Both these factors have increasing significance as the industry moves ahead in design applications of materials difficult to produce in the original configuration and in the final machined condition.

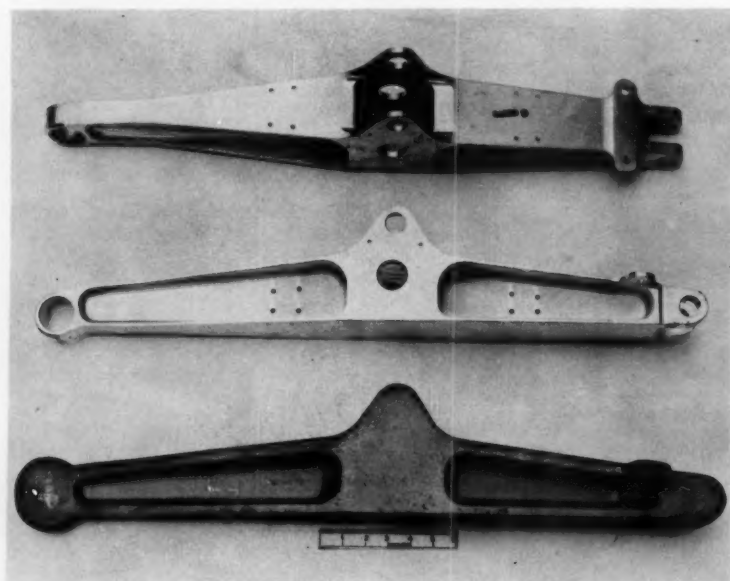


Fig. 5 — Forged 4340 steel wing flap track carriage.

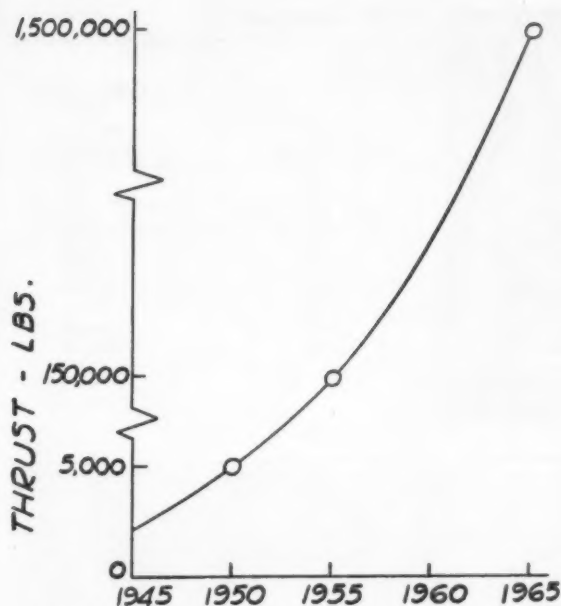
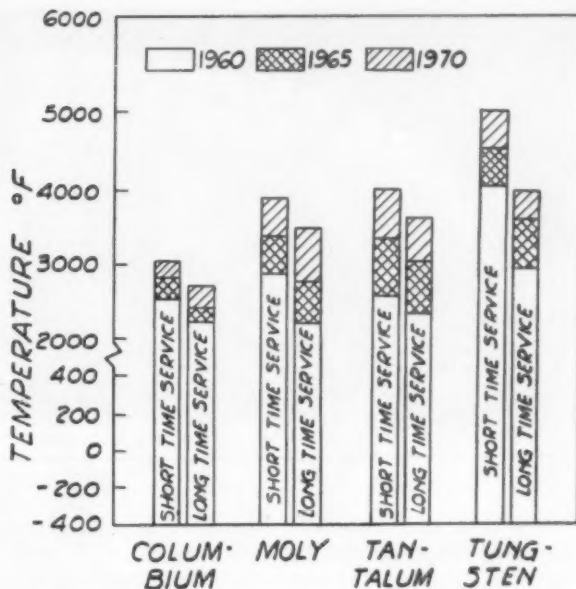


Fig. 6 — Power plant trends.

#### CASTING NEEDS

The hindrances to wider acceptance of aerospace castings require early solution as future requirements are envisioned. Technical feasibility is well established for commercial travel and deep space exploration at many times the speed of sound. Events of this nature are, in part, due to the rapid developments in power. Figure 6 is a graphic representation of the power available for use over a period of years. Power plant thrust will increase from 3000 lb in 1945 to 1,500,000 lb in 1965. Developments of this nature have suddenly created technological deficiencies in material requirements. The Aerospace Industries Association 1960 Forecast<sup>1</sup> emphasized these deficiencies by the following statement:

"A recent formal report to the National Academy of Sciences concluded that 'major end-item programs in all areas of national security (defense, atomic energy

Fig. 8 — Forecast of thermal capability of refractory metals.<sup>1</sup>

and space) are now up against a serious materials' road block. The properties of most presently available materials are inadequate for the high performance end items that must be made to withstand the severe temperature, pressure, radiation, corrosion and stress conditions of space-age environments.' — fabricability and cost are critical factors."

Figures 7 and 8 show the potential capabilities of various metals. It will be noted that growth is greatest in beryllium, titanium, stainless steel, super alloys and the refractories. There is intensive effort to clear the roadblocks to their ultimate capabilities. Comparable effort is required to make them available in the form of castings at an early date.

#### DOLLAR SAVINGS FROM CASTINGS

Fabricability and cost require constant surveillance in designs. Increasing attention is being focused on

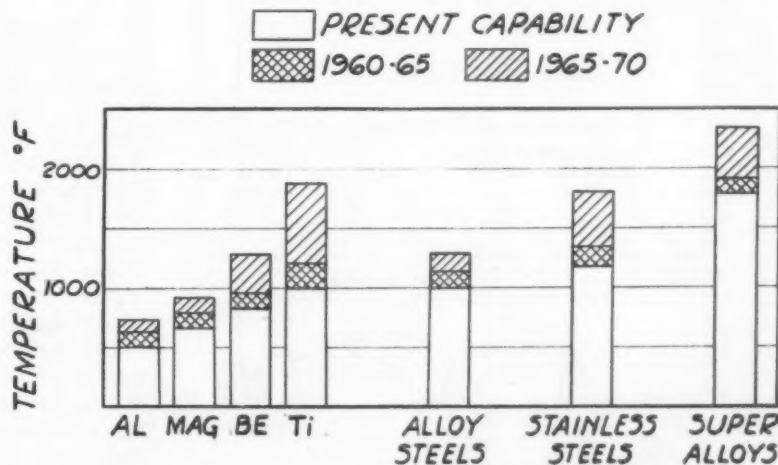
Fig. 7 — Forecast of thermal capability of metals.<sup>1</sup>

TABLE 4—ESTIMATED MATERIAL COST SAVINGS FROM CASTINGS

Material	Forging or Casting Material, Cost/lb, \$	Forging or Casting, Cost/lb, \$	Material Loss in Producing 100 Lb of Finished Parts <sup>1</sup>		Dollar Savings from 100 Lb of Castings, \$
			Conventional Forgings with 77% Reduction, \$	Castings with 30% Reduction, \$	
Air Melt Steel	0.20	0.75	250	30	220
Vacuum Melt Steel	1.00	1.50	500	65	435
R-235 Steel	5.00	7.50	2,330	305	2,025
Titanium	4.50	12.00	3,850	495	3,355
Zirconium	7.00	20.00	6,435	830	5,605
Molybdenum	25.00	50.00	14,190	1,830	12,360
Tantalum	50.00	125.00	36,675	4,730	31,945
Beryllium	60.00	150.00	44,075	5,675	38,400
Columbium	100.00	250.00	73,350	9,460	63,890

## 1. Assumed Value of Scrap Recovery:

10% Material Cost of Titanium, Zirconium and R-235 Steel.

30% Material Cost of Refractories.

Scrap Value Neglected for Air and Vacuum Melt Steel.

this subject in realization that there is a limit to available dollars. In designs ahead, the engineer must have the means, more than ever, to reduce his designs to practice with little or no metal removal. The free and easy machining properties as available with aluminum or magnesium are no longer anticipated. Rather, materials which are costly to initially shape and convert to final shape by metal removal processes are being studied.

In consideration of the final part the question is asked, "What else will do the job"? Answer to this question must consider bits and pieces assembled by mechanical fasteners, weldments, brazing, intermetallic bond; forgings and castings. No one method of part manufacture will do all jobs in the best possible manner. All types are needed. Castings become desirable with increase in shape complexity, and when other design solutions are more costly.

Even with moderate complexity where a forging could be used, a high cost penalty from material losses in conversion to the finished part is found. This is particularly true in the newer materials. For example, large forgings in columbium are limited

to simple shapes, such as the pancake type with little definition. Similar conditions prevail with forged tantalum. Tungsten has not been moved into much shape by conventional forging practices.

Table 4 is a summary of cost savings in material to be realized by good castings replacing forgings at the present state of development. As an example, savings of \$63,000 are possible from 100 lb of finished columbium castings. If a 50 per cent reduction in columbium material costs is considered, the savings would amount to approximately \$32,000. The estimates consider 77 and 30 per cent reduction in forging and casting weights, respectively, by metal removal processes. Such savings must receive more than casual attention. They are possible because of inherent capabilities of the casting process to produce parts to or nearly to final size. Further, castings offer an additional bonus by reason of less cost in shaping to final size. Clearly, there are good reasons for accelerating casting developments. The nation's defense budget needs this work to reduce application cost of expensive materials.

## OUTLOOK

There is mixed opinion about future casting requirements. The Aerospace Industries Association 1960 Forecast<sup>1</sup> of various material forms is given in Fig. 9. A decrease in casting uses is forecast. On the other hand, Battelle Memorial Institute<sup>2</sup> reports a forecast of increased steel casting uses from a statement by a Materials Advisory Board Panel on Castings and Powder Metallurgy.

Casting requirements are subject to upward revisions by breakthroughs in casting technology. Breakthroughs will come from those with creative imagination unshackled by convention. Preconceived ideas and stereotyped approaches will not bring desired results. The technical approach to fundamental casting processes is required to bring about solutions rather than improvements in the art of casting.

The outlook is encouraging for high quality castings produced by improved technology. Sign posts in this direction are vacuum degassing, vacuum melting and pouring processes to improve homogeneity, elongation, fatigue and impact properties,<sup>3</sup> new tech-

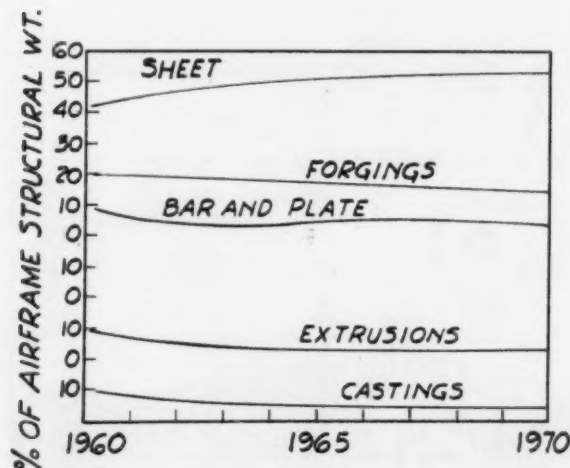
Fig. 9—Forecast of material forms.<sup>1</sup>

Fig. 10 — Forged 7075 aluminum alloy fuselage bulkhead 66 in. in height for an interceptor airplane.

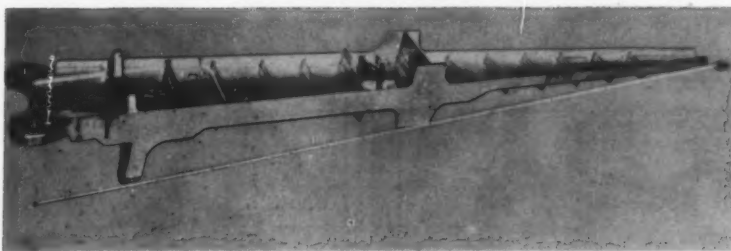
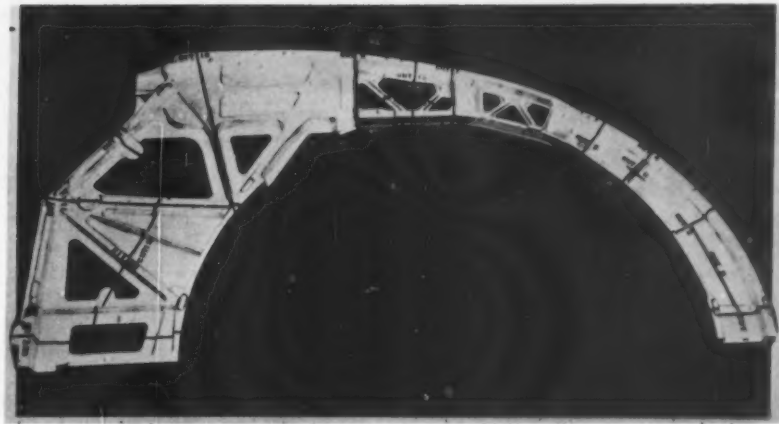


Fig. 11 — Forged 7075 aluminum alloy wing spar 10 ft in length for an interceptor airplane.

niques in melting practices,<sup>4</sup> mold developments, new approaches to formed shapes, such as sintering of pressed metal powders and slip castings, possibilities of grain refinement by ultrasonic energy and metallurgy best suited for casting processes.

The slip casting process is cited as an example of encouragement in casting development. A 1/2-in. diameter bar approximately 6 in. in length was slip cast in type 316 stainless steel alloy by the author's company.<sup>5</sup> Table 5 summarizes the results.

Casting sizes and complexity similar to the forgings of Figs. 10 and 11 could be used to advantage. Until this plateau of development is reached, there are innumerable casting requirements in the smaller sizes due to high density of aerospace vehicles. Quality comparable to good wrought products is desired, close dimensional control and minimum section thickness of 0.060 in. to reduce the compounding effects of weight and cost of shaping to final size. The achievement of these objectives cannot be said to be impossible by application of growing technology.

TABLE 5 — TYPE 316 STAINLESS STEEL SLIP CASTING PROPERTIES

Physical Properties	
Density of sintered tensile bar, slip casting . . . .	7.9 gr/cc
Theoretical density, wrought . . . . .	7.86-7.94 gr/cc
Mechanical Properties	
Slip Casting	
Yield strength, psi . . . . .	27,100
Ultimate strength, psi . . . . .	74,800
Elong., % in 2 in. . . . .	57.5
Wrought	
Yield strength, psi . . . . .	32,000
Ultimate strength, psi . . . . .	77,000
Elong., % in 2 in. . . . .	50.0

## CONCLUSIONS

The aerospace industry is one of dynamic action, and this type of energy is needed in all industries supporting the product. The casting industry has an important role in this support.

Maximum application of castings has been restricted by certain chronic defects. Alternate design solutions are used for reasons of weight saving and structural reliability. The solutions are not always the most economical approach, which condition becomes increasingly important in application of materials to withstand severe temperature environments.

Castings are a necessary form of structure in beryllium, titanium, stainless steels, super alloys and the refractories. They offer large potential savings in material cost and shaping to final size by metal removal processes.

The outlook for high quality castings is encouraging, because of recent technical developments in fields related to foundry techniques.

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# MAGNESIUM-SILVER- DIDYMIUM-ZIRCONIUM CASTING ALLOY QE22A

by D. J. Whitehead

## ABSTRACT

Magnesium casting alloy QE22A\* (Mg-2.2 per cent Di-2.5 per cent Ag-0.6 per cent Zr) combines high yield strength at room temperature with good tensile properties at temperatures up to 600 F (316 C). The alloy also possesses good fatigue characteristics, is free from stress corrosion troubles, and has good long term creep strength at temperatures up to about 400 F (204 C).

QE22A has similar castability to that of other rare earth containing magnesium alloys and is weldable by the argon-arc or heli-arc processes. The alloy shows excellent agreement between the tensile properties of separately cast test bars and test pieces cut from the casting. QE22A should find application for high quality premium grade castings for the aircraft and missile industries.

## INTRODUCTION

There are today a considerable number of magnesium alloy specifications available to users of sand and permanent mold castings. The alloys may be conveniently grouped into four categories:

1. *The classical alloys* based on the Mg-Al-Zn-Mn system, e.g., AZ91C, AZ92A, AZ63A and AZ81A.
2. *The high temperature creep resistant alloys* containing rare earth metals or thorium and grain refined with zirconium, e.g., EZ33A, HZ32A and HK31A.

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\*The composition of QE22A is covered by U.S. Patent No. 2,549,955.

3. *The high yield strength Mg-Zn-Zr alloys*—ZK51A.
4. *The hybrid alloys* such as ZH62A and ZE41A, containing substantial amounts of zinc together with thorium or rare earth metals and zirconium. They combine some of the advantages of groups 2 and 3.

## Aircraft Industry Alloys

The alloys described in the present paper have fairly expensive alloying ingredients and along with those in groups 2, 3 and 4 are mainly directed to the aircraft industry. Although they bear some resemblance to group 4 alloys, they break new ground in that they are based on a new alloy system namely, magnesium-didymium-silver-zirconium. They take advantage of three effects.

Only the second of these effects is novel, its discovery being made in England by R. J. M. Payne and N. Bailey<sup>1</sup> of J. Stone & Co. (Charlton) Ltd.

There is a considerable patent literature on magnesium-base alloys containing the individual rare earth metals in various proportions and Leontis,<sup>2,3</sup> and Leontis and Feisel<sup>4</sup> have discussed their properties. Alloy EK31XA (magnesium-3 per cent didymium, 0.6 per cent zirconium)<sup>5</sup> was the first attempt to make commercial use of an alloy containing fractionated rare earths as distinct from ordinary cerium mischmetal. Payne and Bailey<sup>6</sup> describe the effects of silver additions to such alloys, and the British alloys MSRA and MSRB, and their U.S. equivalent QE22A, are the commercial result of this work.

The alloys show high yield strength, good tensile strength and fatigue properties which are maintained up to 600 F (316 C). The composition ranges be-

ing worked to and the respective specification minimum tensile properties are given in Table 1.

The casting qualities of the alloys are generally good and similar to those of other rare earth containing magnesium alloys. The alloys are used in the solution heat treated and aged condition (T6) only.

### TESTING PROCEDURES

The standard British separately cast test bar for sand cast magnesium alloys was used for the majority of the tests recorded in this paper. This is a one in. round, vertically cast test bar (Form B, British Standard 2L.101), and a 0.564 in. diameter, 2 in. gage length specimen is machined from it for tensile test. With some magnesium casting alloys rather higher tensile properties are obtained with the cast to size A.S.T.M. type 0.5 in. diameter test bar than with the British bar. British practice calls for the determination of 0.1 per cent yield stress (proof stress) rather than 0.2 per cent yield stress. Where 0.1 per cent yield stress values are quoted, an approximate conversion to the 0.2 per cent offset value may be obtained by increasing the former values by 10 per cent.

Elevated temperature tensile and creep tests were carried out in accordance with British Standards 1094 and 1687. Elevated temperature yield strengths were determined at a strain rate of 0.0005 in./in./min, and tensile strength at a strain rate of 0.10 in./in./min. The soaking time at temperature prior to tensile testing was one hr and 16 hr for long term creep testing.

Melting and alloying procedures for Mg-Ag-Di-Zr alloys are similar to other Mg-RE-Zr alloys. Melts were prepared from approved pre-alloyed ingots to Specifications DTD5025 and DTD5035 or alternatively from 99.95 per cent purity magnesium. Silver was added as pure bar silver and didymium as a magnesium-didymium hardener alloy. The didymium contained 80-85 per cent neodymium, 15-20 per cent praseodymium. Zirconium was alloyed via a magnesium zirconium hardener.

### MECHANICAL AND PHYSICAL PROPERTIES

#### Tensile Properties

It will be noted from Table 1 that the British alloys MSRA and MSRB have chemical compositions which differ only by about one per cent didymium. The alloys are comparatively insensitive to in-

crease in silver content when this exceeds 2 per cent, but changes in didymium have fairly marked effects on properties. Figure 1 illustrates the effect of didymium content on the properties of British separately cast test bars containing 2.5 per cent Ag and 0.6 per cent Zr.

Although maximum yield strength is obtained with a didymium content approaching 3 per cent, it is evident that at this level the alloy is rather brittle with considerably reduced elongation values. Maximum tensile strength is obtained at only 1.5 per cent didymium. This is the reason for the existence of two alloys in the British specifications. MSRB was selected to provide an alloy of high yield

TABLE 1—CHEMICAL COMPOSITIONS AND MINIMUM TENSILE PROPERTIES OF MAGNESIUM-SILVER-DIDYMIUM-ZIRCONIUM ALLOYS

Alloy	Spec.	Composition, %			0.1	0.2	Ten. El.
		Di	Ag	Zr	% yield, kpsi	% yield, kpsi	
MSRA, British D.T.D., 5025		1.2-2.0	2.0-3.0	0.4 min.	22.4		34.8 4
MSRB, British D.T.D., 5035		2.0-3.0	2.0-3.0	0.4 min.	24.6		34.8 2
QE22A, T6, U.S. Tentative		1.8-2.5	2.0-3.0	0.4 min.		25.0 35.0	2

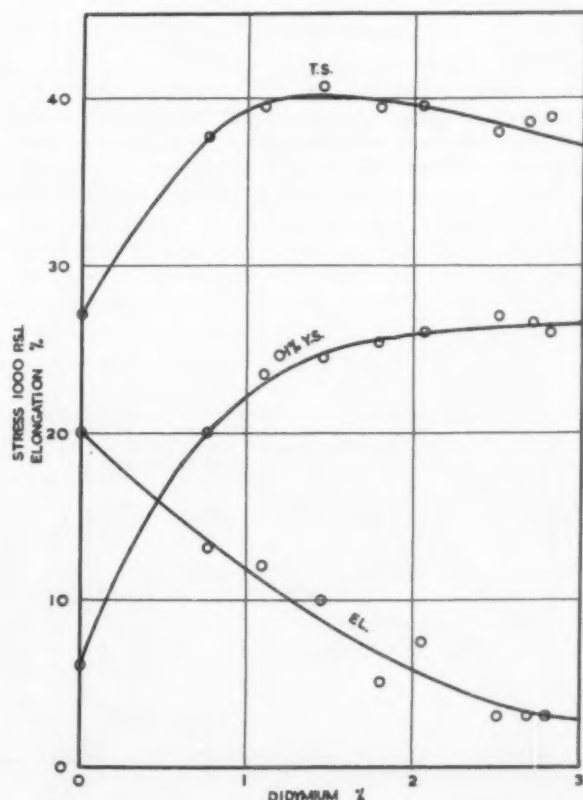


Fig. 1—Didymium content effect on tensile properties of QE22A-T6 type alloys (British test bars).

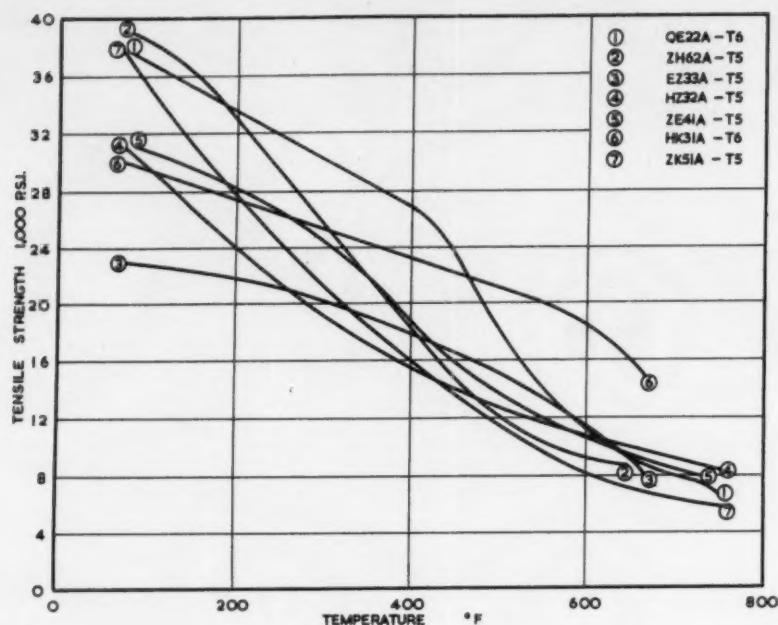


Fig. 2 — Temperature effect on tensile strength of various magnesium casting alloys (British separately cast test bars).

TABLE 2 — MINIMUM TENSILE PROPERTIES FOR VARIOUS MAGNESIUM CASTING ALLOYS (SEPARATELY CAST TEST BARS — A.S.T.M. B80 SPECIFICATION)

Alloy	0.2% yield, 1000 psi	Tensile, 1000 psi	Elong., % 2 in.
HK31A-T6	13	27	4
EZ33A-T5	14	20	2
AZ92A-T6	18	34	1
EK31XA-T6*	19	31	2 1/2
ZK51A-T5	20	34	5
ZH62A-T5	22	35	4
QE22A-T6*	25	35	2
ZK61A-T6	25	40	5

\*Tentative values.

strength without particular regard to ductility while MSRA alloy is the more ductile composition retaining good yield strength. A single intermediate alloy composition (QE22A) is presently considered adequate in the U.S.A.

Table 2 lists the specification tensile values for various magnesium casting alloys, and indicates that QE22A is in the high strength category.

The rare earth metal content of QE22A alloy results in good retention of strength at elevated temperatures. Figures 2 and 3 show the effect of temperature on the tensile and yield strength of British type test bars in several commercially used rare earth

Fig. 3 — Temperature effect on 0.2 per cent yield strength of various magnesium casting alloys using a strain rate of 0.005 in./in./min (British separately cast test bars).

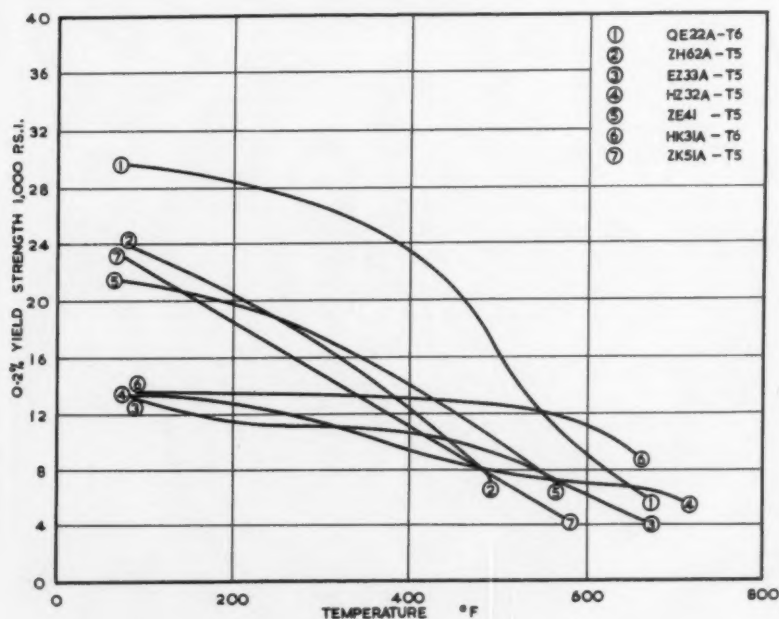
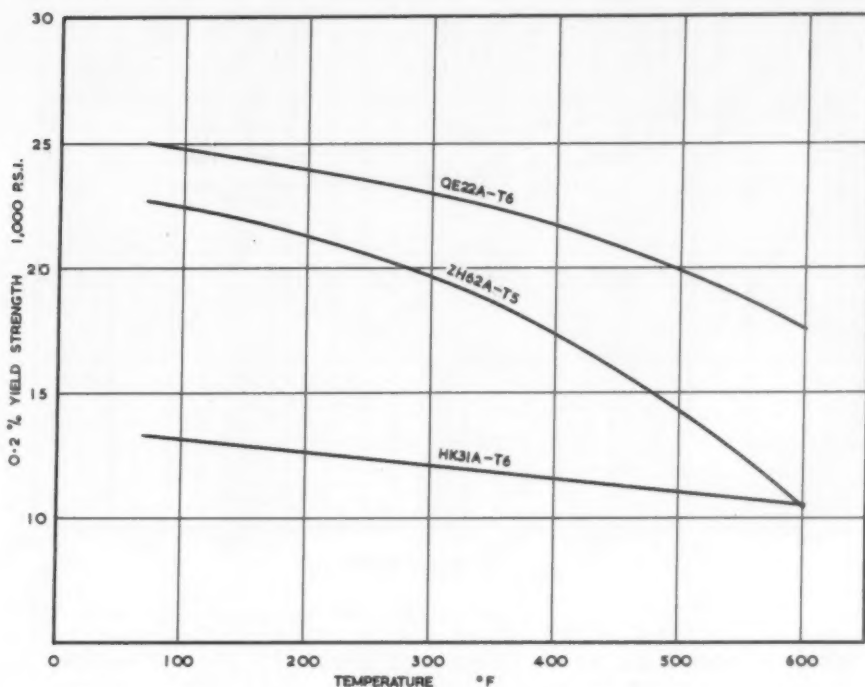


Fig. 4 — Temperature effect on 0.2 per cent yield strength of QE22A-T6, ZH62A-T5 and HK31A-T6 alloys tested at a strain rate of 0.060 in./in./min (after Gronvold<sup>8</sup>).



and thorium containing alloys. QE22A alloy shows the best yield strength up to 540 F (282 C) and tensile strength up to 470 F (243 C). At temperatures higher than these the more stable medium strength thorium alloy HK31A gives higher tensile properties.

The above data apply only however to tests carried out in accordance with the test procedure presented previously in this paper. Table 3<sup>7</sup> lists elevated temperature data on A.S.T.M. type bars using a strain rate of 0.005 in./in./min to one per cent strain and 0.1 in./in./min to fracture and with a heating time of less than one min. The shorter exposures at temperature and higher strain rate result in considerably higher strength values.

TABLE 3 — TEMPERATURE EFFECT ON TENSILE PROPERTIES OF QE22A-T6 (SEPARATELY CAST TEST BARS)

Temp., F	No. of Tests		0.2% Y.S., 1000 psi	T.S., 1000 psi	Elong., %
75	51	Avg.	29.6	39.2	3.8
		Min.	26.9	37.7	1.2
200	1		29.4	35.6	25
300	1		26.6	31.2	24
400	1		24.6	28.2	22
500	1		20.4	24.4	37
600	1		12.0	15.1	51
700	1		6.1	7.3	82

There are a number of applications for this type of alloy for missile castings where exposure times at maximum temperature and load are short and rates of loading high. The consequences of using alloys which are not metallurgically stable at temperature may hence not be serious. In contrast to HK31A and EK31XA alloys, QE22A is particularly

sensitive to rate of loading. W. Gronvold<sup>8</sup> and others have investigated this, and Fig. 4 compares the yield strengths of QE22A with ZH62A and HK31A at a strain rate of 0.060 in./in./min and a 30 sec soak time. Under such conditions, QE22A is the strongest magnesium casting alloy at elevated temperatures.

#### Stability at Elevated Temperatures

Figures 5 and 6 show the effect of holding QE22A-T6 alloy at 482 F (250 C) and 572 F (300 C) on room temperature tensile strength and 0.1 per cent yield strength. The 0.1 per cent yield strength is considerably more affected than tensile strength, and the alloy rapidly overages at both temperatures. At 392 F (200 C) limited data indicate that QE22A-T6 is more stable, 350 hr exposure resulting in 80 per cent retention of the original 0.1 per cent yield strength and 90 per cent of the tensile strength.

Elevated temperature tensile properties are similarly affected by overaging. Table 4 shows how the 0.1 per cent yield stress and tensile strength at 482 F (250 C) and 572 F (300 C) are affected by exposure at these temperatures.

#### Creep Properties

QE22A-T6 alloy has good long term creep resistance at moderately elevated temperatures. Figures 7, 8 and 9 give stress-time relationships for specified creep strains at 302 F (150 C), 392 F (200 C) and 482 F (250 C). Within this temperature range the alloy has similar creep strength over 1000 hr tests to EZ33A-T5 alloy.

#### Fatigue Properties

Table 5 gives rotating bending fatigue strengths at temperatures up to 482 F (250 C). QE22A-T6 shows excellent fatigue strength with some notch sensitivity.

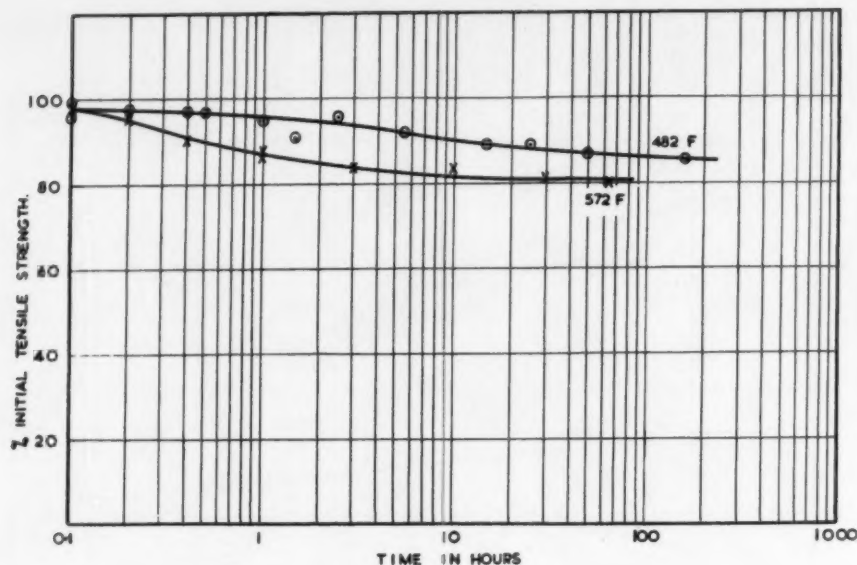


Fig. 5—Overaging at 482 and 572 F effect on tensile strength of QE22A-T6 alloy (British separately cast test bars).

TABLE 4—EXPOSURE AT 482 F AND 572 F EFFECT ON THE TENSILE PROPERTIES OF QE22A-T6 SEPARATELY CAST TEST BARS

Property	Temp., F of Exposure and Testing	% of Initial Property Exposure time (hr) <sup>a</sup>		
		10	50	100
Tensile strength	482	87	75	72
0.1% yield stress	482	85	69	66
Tensile strength	572	82	71	68
0.1% yield stress	572	76	67	62

a. Includes one hr at test temperature prior to testing. British type test bars.

Strain rates in./in./min. — Yield strength 0.0005.

Tensile strength 0.10.

At moderately elevated temperature, e.g., 392 F (200 C), QE22A-T6 has the highest fatigue strength of any magnesium casting alloy so far tested.

#### Shear Strength

Table 6 gives shear strength values for specimens machined from QE22A-T6 separately cast tests. The values are similar to recently reported results<sup>5</sup> for EK31XA-T6.

#### HEAT TREATMENT OF QE22A-T6 ALLOY

The figures shown in Table 8 illustrate the magnitude of the effects of solution heat treatment and aging on the properties of QE22A.

The alloy is only attractive in the T6 condition.

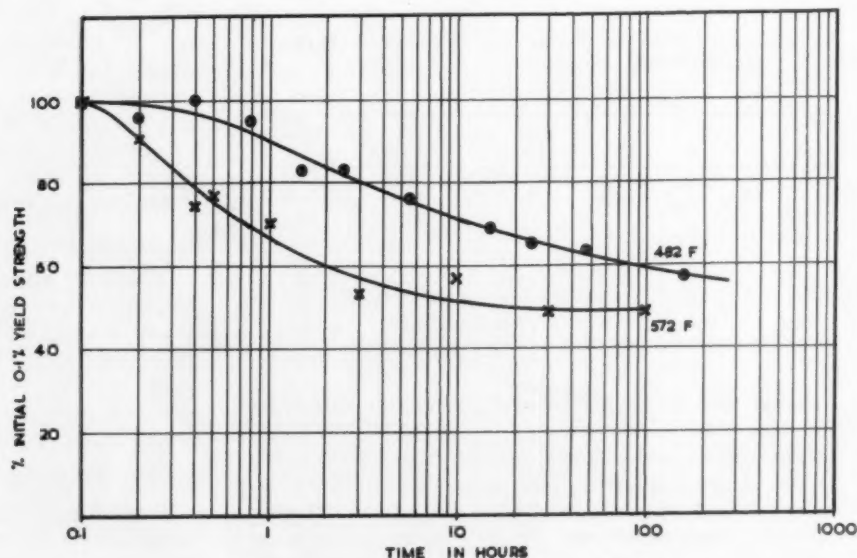


Fig. 6—Overaging at 482 and 572 F effect on 0.1 per cent yield strength of QE22A-T6 alloy (British separately cast test bars).

Fig. 7 — Stress/time relationship for specified creep strains at 302 F for QE22A-T6 alloy.

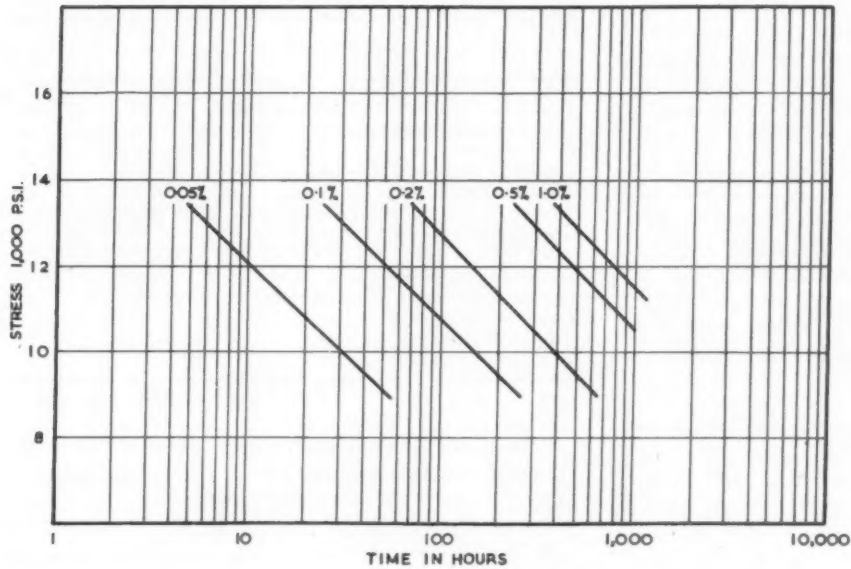
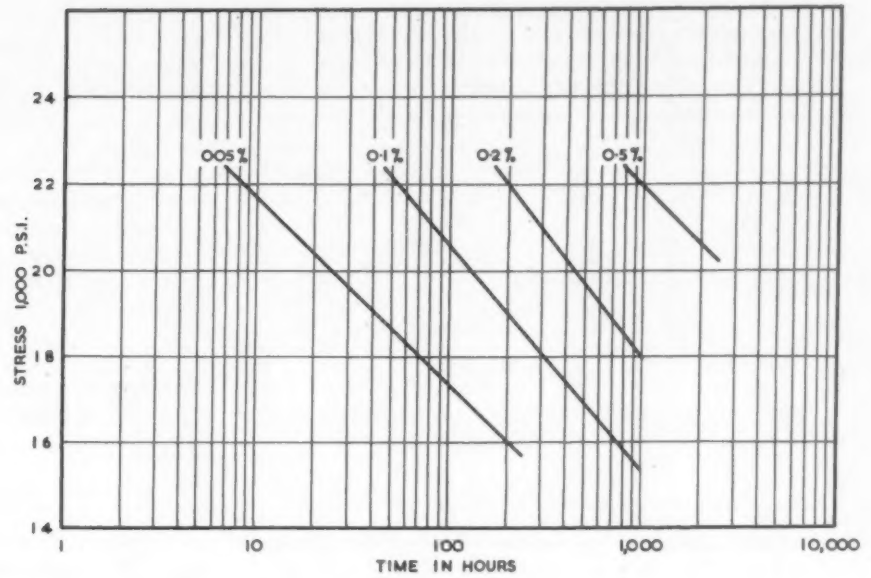


Fig. 8 — Stress/time relationship for specified creep strains at 392 F for QE22A-T6 alloys.

Fig. 9 — Stress/time relationship for specified creep strains at 482 F for QE22A-T6 alloy.

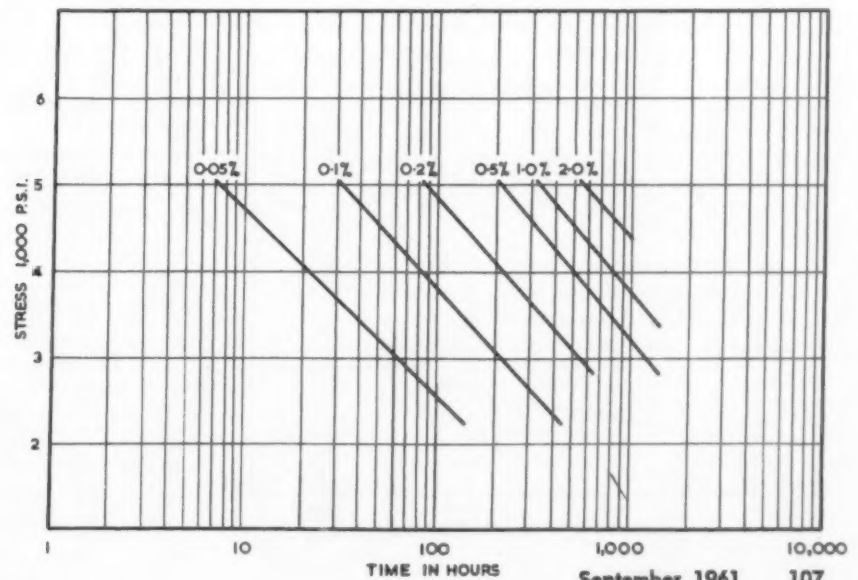


TABLE 5—FATIGUE PROPERTIES OF QE22A-T6 AND OTHER MAGNESIUM CASTING ALLOYS (WOHLER TYPE TESTS ON SEPARATELY CAST TEST BARS)

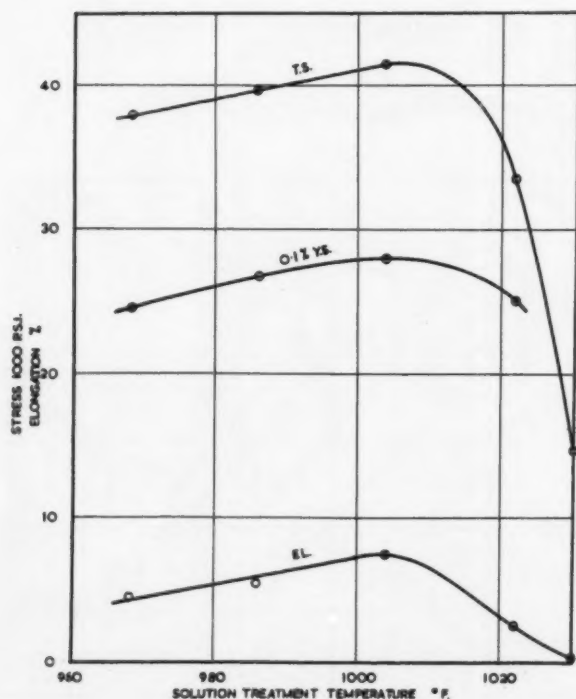
Alloy	Test Temp., F	Fatigue Endurance Value, 50 × 10 <sup>6</sup> cycles, 1000 psi	
		Unnotched	Notched*
QE22A-T6	75	14.5	9
	392	13-17†	8-10†
	482	12.5	
EZ33A-T5	75	9.6-10.5	7.4-8.3
	392	7.3	
	482	6.2	
HK31A-T6	75	9.0-10.0	
	392	8.3	
	482	7.4	
HZ32A-T5	75	9.5-10.5	7.8-10.0
	392	7.5	
	482	3.6	

†R.R. Moore fatigue tests; stress for 10<sup>8</sup> cycles.<sup>7</sup>

\*Stress concentration factor = 2.

### Solution Treatment

Figure 10 shows how variations in solution treatment temperature effect the properties of QE22A-T6. Four hr solution treatment time is sufficient to achieve good properties and 8 hr is not normally exceeded. The usual temperature is 980 F (527 C) although temperatures up to 995 F (535 C) may be employed for castings where there is little risk of distortion. The solidus temperature is approximately 1022 F (550 C). Exceeding 1022 F (550 C) during solution treatment results in a catastrophic fall in tensile properties, frequently accompanied by cracking of the castings on quenching, coarse grain size and distortion.



Forced air circulation furnaces with good temperature control equipment and absence of thermal gradients in the chamber are hence highly desirable. Sulfur dioxide (1.5-2 per cent) gas is introduced into the furnace atmosphere during solution treatment to inhibit oxidation. Low sulfur dioxide concentrations can result in oxidation pits forming on the castings and, in severe cases, furnace fires.

The high temperature heat treatment required for QE22A demands that consideration must be given to the risk of distortion due to creep. Figure 11 illustrates the effects of temperature and time on

TABLE 6—TEMPERATURE EFFECT ON SHEAR STRENGTH OF QE22A-T6 ALLOY

Testing Temp., F	No. of tests	Double Pin Shear, 1/8-in. dia. 1000 psi
75	2	23.2
400	2	18.4
500	2	15.8
600	2	11.8

Data source ref. 7.

TABLE 7—SOME PHYSICAL AND OTHER PROPERTIES

Specific Gravity	1.82 (0.0655 lb/cu in.)
Coefficient of thermal expansion per degree C, 20-200 C	26.7 × 10 <sup>-6</sup>
Thermal Conductivity CGS units 20 C	0.27
Electrical Conductivity mho/cu cm 20 C	14.6 × 10 <sup>4</sup>
0.1% compressive yield stress, 1000 psi	22.5-27
Compressive ultimate strength, 1000 psi	45-55
Brinell hardness, 500 kg	78

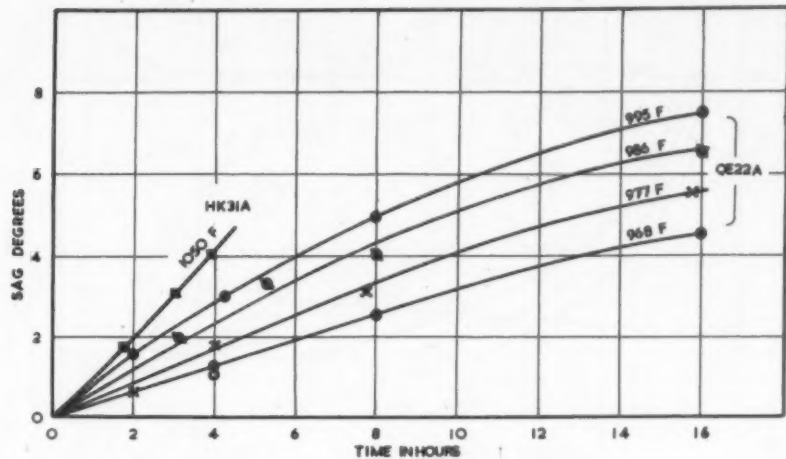
TABLE 8—HEAT TREATMENT EFFECT ON THE TENSILE PROPERTIES OF QE22A SEPARATELY CAST TEST BARS\*

Condition	0.1 % yield stress, 1000 psi	Tensile Str., 1000 psi	Elong., % 2 in.
As-cast	14.8	25.4	7.5
As-cast and aged T5	17.9	24.2	2
Solution treated and quenched T4	11.9	30.0	15
Solution treated, quenched and aged T6	26.0	39.0	4

\*British type test bars.

Fig. 10—Solution heat treatment temperature (4 hr) effect on tensile properties of QE22A-T6 alloy with composition of 2 per cent Di, 2.5 per cent Ag, Zr (British separately cast test bars).

Fig. 11 — Sag of QE22A and HK31A alloys at solution treatment temperatures.



the distortion of QE22A and HK31A during solution treatment. A standard 0.564 in. diameter, 2 in. gage length, machined tensile test piece of the form, shown in Fig. 12, was used for this investigation. The test bars were clamped at one end and heat treated horizontally. Sag was measured as the angle subtended by the free end of the bar with the horizontal after air cooling to room temperature.

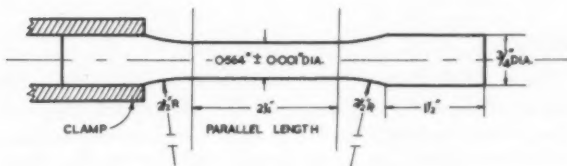


Fig. 12 — Sag test specimen.

It can be seen from Fig. 11 that although HK31 creeps more rapidly at 1050 F (566 C) than QE22A at 968-999 F (520-537 C), the accepted time of 2 hr for solution treating HK31A results in slightly smaller deflections than occur with QE22A solution treated 8 hr at 968-986 F (520-530 C). However reduction of the solution treatment time of QE22A to 4 hr at 977 F (525 C) gives a similar level of distortion to that applying to HK31A. The sag of both HK31A and QE22A is appreciably worse than that of AZ81A heat treated at 780 F (416 C), and necessitates considerably more attention being paid to support fixtures when heat treating slender castings.

#### Quenching

Rates of diffusion are sufficiently slow in most magnesium base alloys that air cooling after solution treatment is normally sufficient to guarantee adequate response of the alloy in subsequent aging at elevated temperature. Busk and Anderson<sup>9</sup> have shown however that the tensile and fatigue properties of magnesium-aluminum-zinc alloys may be improved by water quenching, and K. E. Nelson<sup>5</sup> advocates accelerated cooling of EK31XA alloy for similar purposes. QE22A alloy is sensitive to rate of cooling

after solution heat treatment, and Table 9 illustrates that water quenching is necessary if the best tensile properties are to be realized.

TABLE 9 — TENSILE PROPERTIES OF QE22A-T6 ALLOY SEPARATELY CAST TEST BARS\* QUENCHED FROM 980 F AND AGED 8 HR AT 392 F

Cooling Medium	Average Tensile Properties		
	0.1% yield stress, 1000 psi	Tensile str., 1000 psi	Elong., %
Still air	20.8	33.6	3.5
Air blast	24.0	36.2	3.0
Water (150 F)	25.6	39.2	3.8

a. British type test bars.

Quenching in light oil has also been found to give good tensile properties, and cold water quenched alloy does not give appreciably higher properties than hot water quenched material. Water at 140-180 F (60-82 C) is hence the normal quench medium for QE22A-T6.

The main variable on water quenching is the time required for transferring the charge from the heat treatment furnace to the quench tank. The major factor which affects the significance of prequench air cooling is the section thickness or ratio of surface area to mass of the casting. Table 10 illustrates how prequench delays affect the tensile properties of 1/2-in. sand cast QE22A-T6 plate.

TABLE 10 — QUENCH DELAY EFFECT ON THE AVERAGE TENSILE PROPERTIES OF QE22A-T6 1/2-IN. PLATE CASTINGS. SOLUTION TEMPERATURE 975 F

Delay in sec prior to quench	0.1% yield stress, 1000 psi	Tensile, 1000 psi	Elong., % 2 in.
0	26.2	38.5	5
15	25.6	37.0	3
30	25.8	37.2	3
60	25.6	37.0	3.5
120	24.4	34.1	3

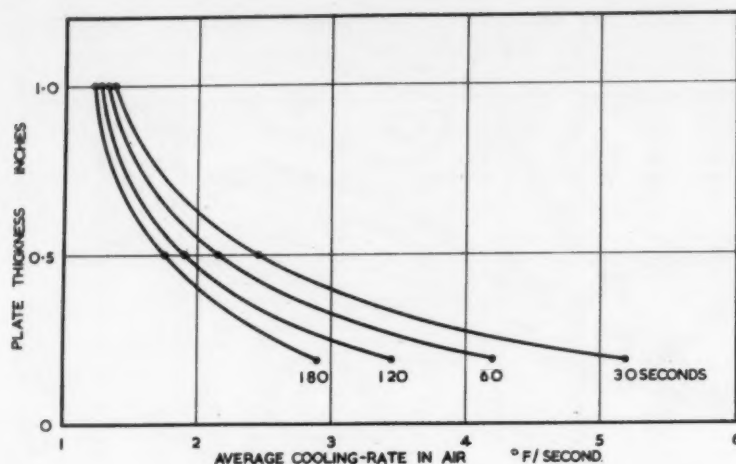


Fig. 13 — Section thickness effect on air cooling rate of sand cast and solution heat treated QE22A plate.

Similar results were obtained with one in. round test bars and one in. plate, and provided such material is not allowed to air cool below about 850 F (454 C) within a time limit of one min prior to quenching the delay is of little consequence.

With casting sections of less than 0.5 in. rates of air cooling are appreciably faster and the subsolvus temperatures attained with quench delays may be correspondingly lower. A general limitation of 30 sec on the prequench delay is hence considered good practice for QE22A alloy. Figure 13 shows how thickness affects the average cooling rates of QE22A sand cast plates over specific quench delays. The plates were solution treated at 975 F (524 C) and suspended in still air on removal from the heat treatment furnace.

The extreme case of a  $\frac{3}{16}$ -in. plate air cools to 820 F (438 C) in 30 sec. However, the rate of cooling is sufficiently rapid to preserve the solid solution, and even after 180 sec air cooling, i.e., down to 450 F (454 C), a 0.1 per cent yield strength of 24,600 psi was obtained compared with 27,400 psi for the immediately quenched material and 25,300 psi for plate quenched with a delay of 30 sec. The fast rates of cooling associated with water quenching (of the order of 80 F/sec) are hence not essential with QE22A, and other forms of rapid cooling, e.g., water spray, may be used, and provided the average cooling rate is around 5 F/sec good properties will be obtained.

The difficulties with such methods of cooling are those of achieving sufficient chill on thick section castings, and reproducible results with variable shapes and heat treatment loads. Founders hence prefer to water quench, and frequently use existing water quench facilities used for aluminum-base alloys.

The possibility of cracking and distortion must always be considered when water quenching castings. QE22A alloy however is not susceptible to quench cracking, provided the solution heat treatment temperature does not exceed the solidus.\* Warp on

quenching has not presented a problem with normally designed castings. Laboratory tests on thin plates of  $\frac{1}{4}$ -in. and less have shown that distortion can occur, some of which has been due to changes occasioned by solution treatment and the release of casting stresses. Some difficulties may hence be encountered with thin slender castings of appreciable area. However, as indicated previously, less drastic cooling methods may be employed with such castings.

#### Aging

Figure 14 shows how temperature and time of aging affect the tensile properties of separately cast test bars. Maximum 0.1 per cent yield strength and tensile strength are developed at 392 F (200 C). Normal minimum and maximum aging times are 8 and 16 hr, and the alloy is air cooled after aging. It will be observed that appreciable gains in ductility of the fully hardened alloy can only be obtained by underaging and at considerable sacrifice of yield strength.

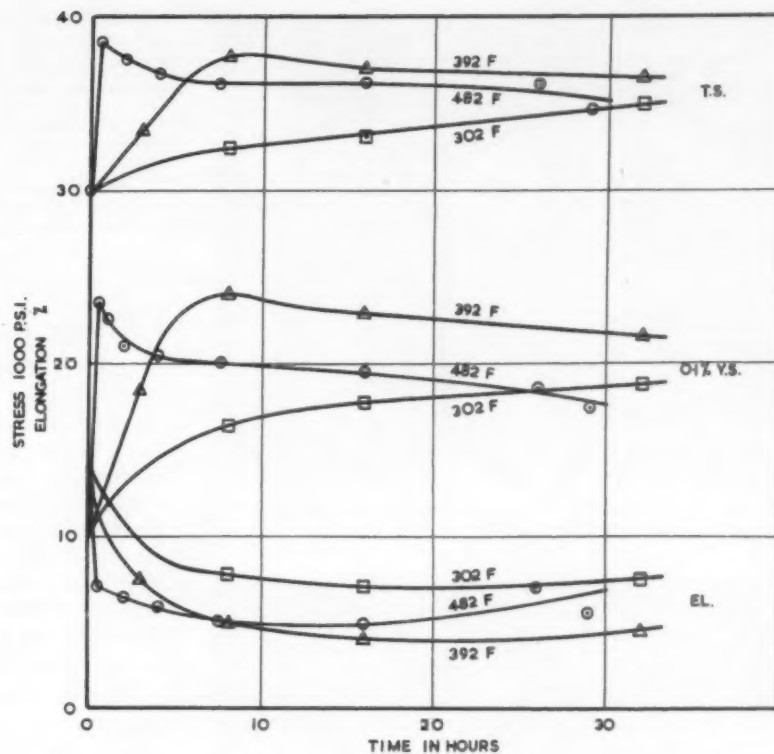
#### Metallography of Heat Treated QE22A

No extensive study of the precipitation process in QE22A alloy has been made. Acetic glycol is a useful grain boundary etchant, but the alloy stains readily due to its silver content and structures within the grain should be interpreted with caution. The as-cast structure (Fig. 15) resembles EK41 and EK-31XA alloys. Solution heat treatment and quenching results in partial solution and coalescence of the magnesium-didymium eutectic phase. Traces of ring-like precipitate are frequently also visible within the grain, and are associated with zirconium or zirconium hydride (Fig. 16).

The effects of overheating are readily revealed by grain coarsening and the curved edges of the eutectic phase (Fig. 17). Inefficient quenching is revealed at high magnifications by the presence of fine precipitate in the grain boundaries (Fig. 18). QE22A alloy must normally be seriously overaged before definite signs of didymium compound precipitation are visible, and it is not usually possible to check aging procedures by microscopic examination.

\*Notched test panels of the type described by Busk and Anderson<sup>9</sup> fail to crack in QE22A alloy when quenched into cold water from temperatures below 1020 F (550 C).

Fig. 14 — Time and temperature of aging effect on properties of QE22A-T6 alloy (British separately cast test bars).



The presence of hydrogen in the furnace atmosphere must be avoided during solution treatment or the alloy will fail to respond to subsequent age hardening and have low yield strength. The presence of  $1\frac{1}{2}$ -2 per cent sulfur dioxide in the furnace atmosphere is sufficient to avoid trouble due to water vapor. When oxidation pits do form on castings however due to incorrect furnace atmosphere, local abnormal microstructures will be found in the metal

immediately adjacent to them (Fig. 19). The grain boundaries are abnormally free to didymium eutectic and heavy precipitation occurs within the grain. Solution heat treatment in hydrogen gives similar structures and low tensile properties. (Table 11).

The effect is thought to be due to precipitation of rare earth and zirconium hydrides during solution treatment. Similar effects have been observed with HK31A-T6 alloy.

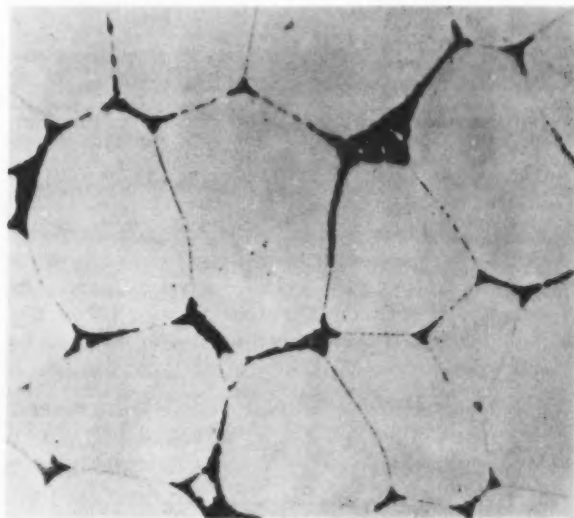


Fig. 15 — QE22A as-cast. Acetic glycol etch. 600 X.

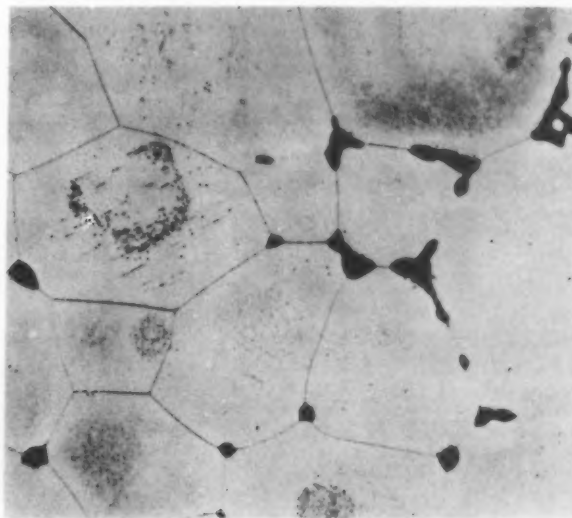


Fig. 16 — QE22A-T6. Acetic glycol etch. 600 X.

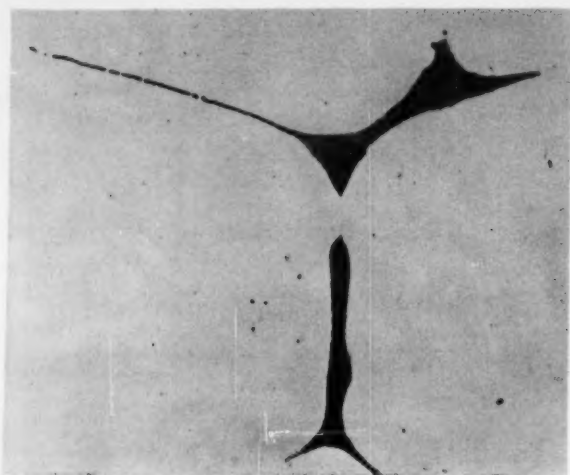


Fig. 17 — QE22A-T6, overheated during solution treatment. Acetic glycol etch. 600 X.

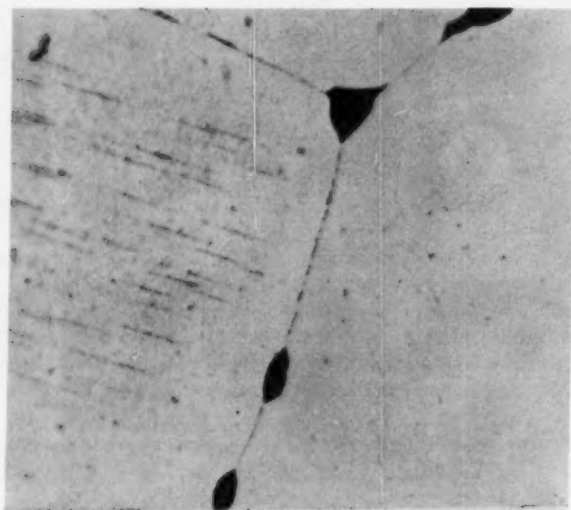


Fig. 18 — QE22A-T6, air cooled from solution treatment temperature. Acetic glycol etch. 1500 X.

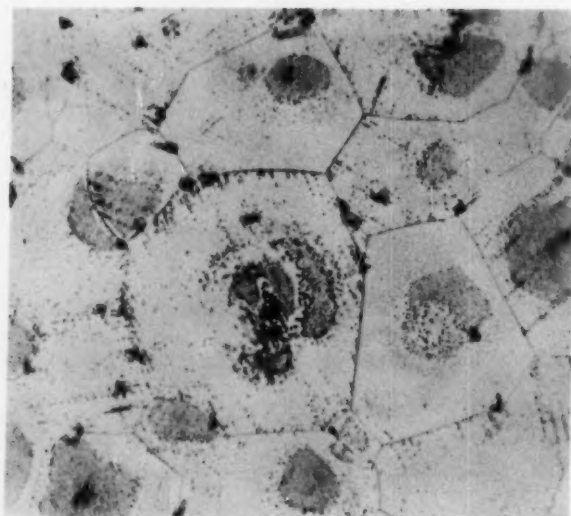


Fig. 19 — QE22A-T6, structure underlying oxidation pit. Acetic glycol etch. 600 X.

TABLE 11 — TENSILE PROPERTIES OF QE22A-T6\*  
ALLOY SOLUTION TREATED IN HYDROGEN  
ATMOSPHERE. (SEPARATELY CAST TEST BARS)

0.1% yield, 1000 psi	Tensile, 1000 psi	Elong., % 2 in.
9.9	28.2	15

\* Solution treated 7 hr 986 F in hydrogen, hot water quenched, aged 16 hr 392 F in air.

#### RARE EARTH METALS COMPOSITION

QE22A alloy has a rare earth metal content of essentially pure didymium comprising 80 per cent neodymium and 20 per cent praseodymium. The cerium, lanthanum and samarium contents are of a low order, i.e., less than one per cent each, and use of a rare earth metal reasonably low in cerium and lanthanum is necessary if the best tensile properties are to be obtained. The number of sources of suitable rare earth metal available at an economic price is limited. Table 12 illustrates the tensile properties obtained on QE22A-T6 type alloys prepared from several different rare earth mixtures.

The tests indicate clearly the importance of a relatively high neodymium content for obtaining good tensile and yield strengths. However there is nothing to be gained by using a rare earth source with a neodymium content in excess of 80 per cent, and indeed there is a tendency for elongation values to fall at high neodymium content. The didymium mischmetal 2 was interesting in that it gave good tensile properties in the 1.2-2.0 per cent RE range with good ductility. It has been observed in particular that this material gives rather higher elongations than 80 : 20 Nd/Pr in the range 1.6-2.0 per cent RE. However yield strength values at higher rare earth contents (2.0-3.0 per cent) are not as high, and on balance the 80 : 20 Nd/Pr (didymium A) is superior.

Certain other conclusions may also be drawn concerning the influence of the individual rare earth metals on the properties of QE22A-T6 type alloys, eg.:

1. Cerium is among the least effective of the commoner rare earths in conferring good tensile properties to QE22A type alloys.
2. Replacement of 50 per cent of the cerium content with a 50-50 mixture of didymium and lanthanum to give cerium mischmetal results in better properties.
3. Reduction of the cerium content of cerium mischmetal by replacement with didymium to give didymium mischmetals 1 and 3 gives a further increase in properties. These are enhanced, but to a lesser degree, if the lanthanum is also replaced by didymium to give didymium A.

It is hence desirable to use a relatively high grade of didymium when alloying QE22A and precautions must be taken to avoid contamination with cerium and lanthanum (e.g., by introduction of cerium mischmetal) if a high level of properties is to be maintained.

TABLE 12 — TENSILE PROPERTIES OF SEPARATELY CAST TEST BARS† OF QE22A-T6 TYPE ALLOYS MADE FROM DIFFERENT RARE EARTH METALS

Rare Earth Type	Rare Earth Analysis, %						Tensile Properties					
							MSRA type (1.7 % RE)			MSRB type (2.5% RE)		
	Nd	Pr	Ce	La	Gd	Other R.E.s.	0.1 % yield, 1000 psi	Tensile, 1000 psi	Elong., % 2 in.	0.1 % yield, 1000 psi	Tensile, 1000 psi	Elong., % 2 in.
Cerium	—	—	99.5	—	—	—	18.6	31.5	6	18.0	27.8	4.7
Cerium Mischmetal	16.9	5.4	50.7	27*	—	—	19.0	32.3	6	20.4	30.3	3
Didymium Mischmetal 1		62†	12	23*	—	—	22.4	35.6	7	23.7	35.6	6
Didymium Mischmetal 2	57	16.6	7.8	5.8	4.8	7.7	23.7	38.3	7.2	24.4	36.0	3.5
Didymium Mischmetal 3	64	14	1	21*	—	—	—	—	—	24.4	34.9	3
Didymium A	79.1	19.9	0.75	—	—	—	25.2	39.4	6	26.0	38.0	3
Didymium B	79.5	12.2	0.6	—	—	7.6	24.8	39.4	6	26.0	36.5	2
Didymium C	85.7	9.9	0.34	3.2	—	—	25.3	38.0	4	25.8	37.8	3
Neodymium	90.4	2.1	2.1	—	—	5.4	24.4	38.2	4	25.7	38.0	2

†Nd + Pr.

\*Includes gadolinium and other rare earth metals.

†British type test bars. All alloys were solution treated 8 hr at 40 F below their solidus temperatures, water quenched and aged 16 hr at 350 - 392 F.

### CASTABILITY

The term castability is a comprehensive one and includes many factors. The main alloy properties which determine the quality and ease of production of magnesium sand castings may be listed as:

1. Hot tearing tendency.
2. Susceptibility to surface sinks.
3. Incidence of microporosity.
4. Sensitivity to mass effect.
5. Tendency to oxide and other inclusions.
6. Fluidity or mold filling capacity.
7. Segregation.

It is normal to gain an assessment of the castability of a new alloy by pouring special shapes designed to emphasize defects attributable to one or more of the above factors, and also by making and examining castings in the production foundry. The latter are usually production castings on which there is a good background of experience, and the characteristics of which are well known. Generally speaking, it is not possible or necessary to determine by laboratory test all the factors listed above. There is however now a reasonable background of casting experience on QE22A alloy which leads to the following evaluation.

#### Tendency Towards Hot Tearing and Cracking

Like other rare earth containing alloys such as EZ33A and EK41A, QE22A alloy is not hot short, and no difficulties are likely to be encountered with cracking on complex castings using established magnesium sand foundry practices. The good weldability of QE22A is a further indication of low cracking tendency.

#### Susceptibility to Sinks

QE22A is more prone to this type of defect than zinc bearing alloys such as EZ33A, ZK51A and AZ-

81A-AZ92A type alloys. Other magnesium alloys with limited freezing ranges, e.g., K1A, HK31A and EK31XA, also show surface sinks and depressions at changes in section and where massive sections solidify under conditions of poor feed. The overall assessment is that QE22A is less susceptible to sinks than K1A and HK31A.

#### Microporosity

QE22A shows some tendency to microporosity when solidifying under conditions of poor feed, and is inferior in this respect to EZ33A alloy. K. E. Nelson<sup>7</sup> has classified QE22A and EK31XA alloys as being comparable to AZ91C and AZ92A alloys. The incidence of microshrinkage in QE22A is related to the didymium content, and hence to the volume of eutectic liquid available to feed the incipient pores. Cerium mischmetal is more effective than didymium in suppressing microporosity for equivalent additions to a magnesium base alloy. MSRA alloy (Di 1.2-2.0 per cent) is more susceptible to microporosity than MSRB alloy (Di 2.0-3.0 per cent), and we classify the alloys in the same general category as ZE41A. Little difficulty should be experienced in making complex castings to high radiographic standards, and English foundries will undertake pressure tight work in the alloy.

QE22A is outstanding in that high properties are obtainable with thick section castings. Table 13 surveys the results of cut up tests in a variety of castings made by both U.S. and English foundries. In the majority of cases the castings were gated and risered as for the normal production magnesium alloy. The test results illustrate two features, namely the relative insensitivity of tensile properties to increase in section and the presence of moderate amounts of microshrinkage. Payne and Bailey<sup>6</sup> have also compared the properties of MSRA and MSRB with other magnesium and aluminum-base alloys

TABLE 13 — TENSILE DATA ON TEST BARS CUT FROM CASTINGS

Type of casting	Alloy	Weight, lb	Range of section size, in.	No. of Test Bars	Min. Tensile Properties				Max. Tensile Properties				Avg. Tensile Properties				Source
					0.1% Y.S.	0.2% Y.S.	T.S.	El., %	0.1% Y.S.	0.2% Y.S.	T.S.	El., %	0.1% Y.S.	0.2% Y.S.	T.S.	El., %	
1. Helicopter air frame	QE22A	14.7	1/4 - 2	9		26.9	35.6	1.5		29.3	38.9	4.0		28.4	37.3	2.9	Dow
2. Aircraft access door	QE22A	20.5	1/4 - 1 1/4	11		25.8	35.5	2.0		30.1	40.3	4.0		28.3	37.2	2.7	Dow
3. Jet engine part	QE22A	51.5	1/4 - 2 1/2	12		27.7	36.8	1.3		29.9	39.6	5.0		28.9	37.6	2.8	Dow
4. Jet engine part	QE22A	49.0	5/8 - 1 1/4	10		27.3	34.8	2.0		29.3	38.2	4.0		28.2	36.6	2.3	Dow
5. Aircraft wheel	QE22A	132	5/8 - 3 1/4	17		26.8	33.7	1.0		29.9	37.7	5.0		28.1	35.7	1.8	Dow
6. Missile casting	MSRB	43	2 1/4	16	22.4		33.2	1.0	25.3		37.2	3.0	24.0		35.2	1.2	M.E.L.
	ZK61A-T6	43	2 1/4	16	16.6		28.4	1.5	19.8		33.2	3.5	17.8		30.5	2.8	M.E.L.
7. Electronic support casting	MSRA	6.5	3/16 - 3/8	18	21.7		32.5	2.5	25.1		38.5	12	23.3		36.3	7.2	M.E.L.
8. Aircraft structural	MSRA	14.9	1/4 - 3	9	24.6		37.6	2	27.1		41.2	7.5	25.8		39.2	5.4	J. Stone
	MSRB	14.9	1/4 - 3	9	24.8		35.8	1	27.5		38.0	5.5	26.2		37.0	3.2	J. Stone
9. Half hoop	MSRA	12.25	1 1/4 min.	9	22.6		37.0	2.5	24.6		39.4	10.5	23.8		38.5	7.9	J. Stone
	MSRB	12.25	1 1/4 min.	9	24.9		35.2	3.0	26.8		37.7	7.0	25.7		37.6	5.0	J. Stone
10. Aircraft structural	MSRB	—	1 1/4	7	24.0		33.1	1.6	26.2		37.4	4.0	25.5		36.0	2.8	J. Stone

All stresses in 1000 psi.

cast into 4 in. dia. x 8 in. long cylinders (Table 14).

Figures 20-22 provide a quantitative indication of the effect of section thickness on QE22A, ZK51, AZ81A and EZ33A alloy using standard size tensile specimens machined from square section slabs. The gating and feeding system selected was such that moderately heavy porosity was obtained with alloys other than EZ33A, and the properties may be regarded as conservative for premium grade castings. The data confirm the comparative insensitivity of QE22A to mass effect compared with other alloys such as AZ81A and ZH62A.

The susceptibility of ZH62A to mass effect has been noted elsewhere,<sup>11</sup> and occurs also with the

other 6 per cent zinc casting alloy ZK61A. Thus casting 6 (Table 13) with a ruling section of 2 1/4-in. x 3 in. gives markedly inferior properties when cast in ZK61A compared to QE22A. High tensile properties are however obtainable from ZK61A with thin section castings. This is reflected in the type of separately cast test bar selected for control of melt quality, and Table 15 compares the tensile properties of A.S.T.M. and British test bars. The test bars of each alloy were cast from the same melt and heat treated together.

The rare earth content of QE22A results in some tendency towards oxide inclusions comparable to that in EZ33A and EK31XA, but less than that in the

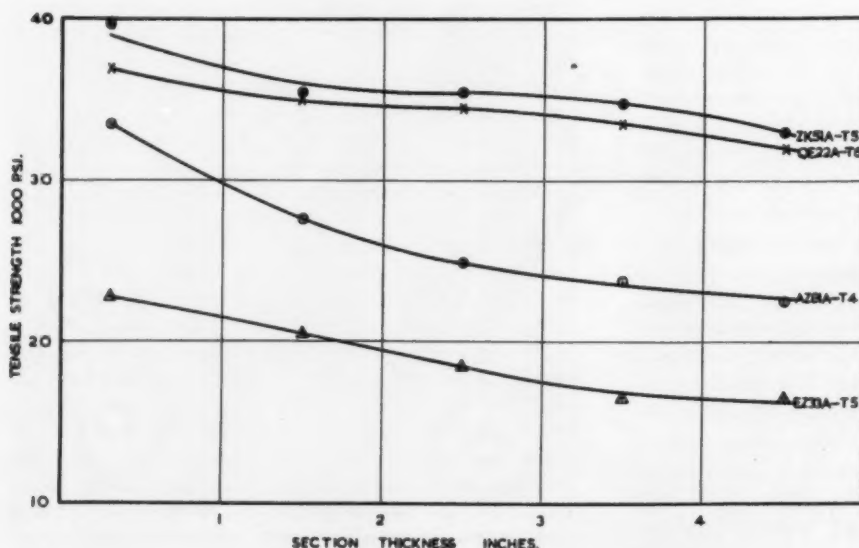
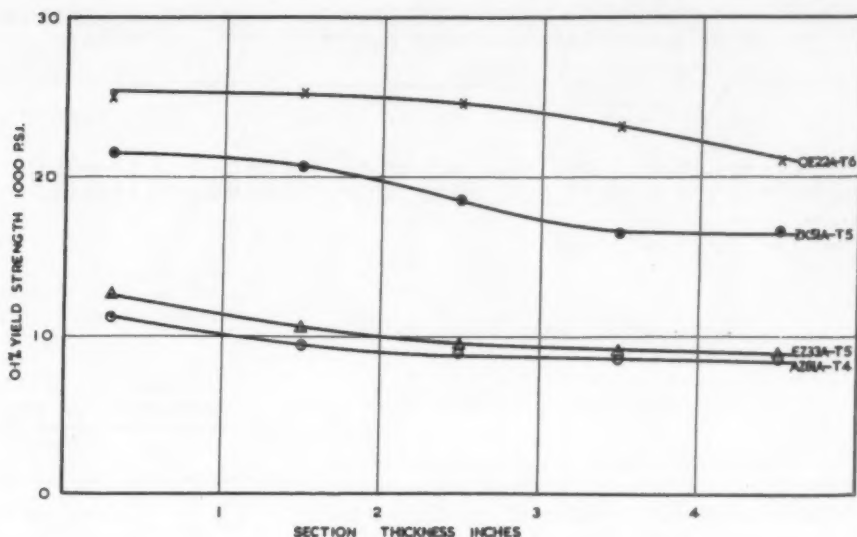


Fig. 20 — Section thickness effect on tensile strength of several magnesium sand casting alloys.

Fig. 21 — Section thickness effect on 0.1 per cent yield strength of several magnesium sand casting alloys.



thorium alloys HK31A and HZ32A. Gating systems must hence be designed with a view to achieving minimum turbulence. A tendency has been observed for oxide inclusions to increase with didymium content (Table 16).

Other inclusions which may be encountered in QE22A are associated with flux, sand and zirconium rich segregates. The incidence of flux and sand inclusions follows a similar pattern to other alloys, and is a function of technique rather than the alloy. K. E. Nelson<sup>7</sup> has observed that the presence of silver apparently results in a slower rate of settling of nonmetallics in the melt than with other alloys. British foundries however have not encountered this tendency.

The mold filling capacity of QE22A is rated as similar to that of EZ33A and intermediate between the fluid Mg-Al-Zn-Mn alloys AZ91C, AZ81A and the sluggish thorium alloys HK31A and HZ32A.

With correct alloying and pouring techniques, the principal form of segregation met in QE22A alloy is of the dense rare earth eutectic type and similar to that described by Skelly and Sunnucks<sup>10</sup> and occurring in EZ33A alloy. It arises from the healing of incipient hot tears and microshrinkage by didymium rich eutectic liquid. Although no systematic investigation of the effects of such segregates on strength properties of QE22A has been made, they are known to have relatively small influence when encountered in EZ33A type alloys. The remedy for such defects normally lies in attention to gating and feeding techniques.

QE22A alloy may be welded by the argon-arc and heli-arc methods using QE22A filler rod. Minor casting defects are readily rectified by this means and high weld efficiencies are obtainable. Preheating of castings to temperatures between 400-500 F (204-260 C) is normally necessary before welding.

Fig. 22 — Section thickness effect on elongation of several magnesium sand casting alloys.

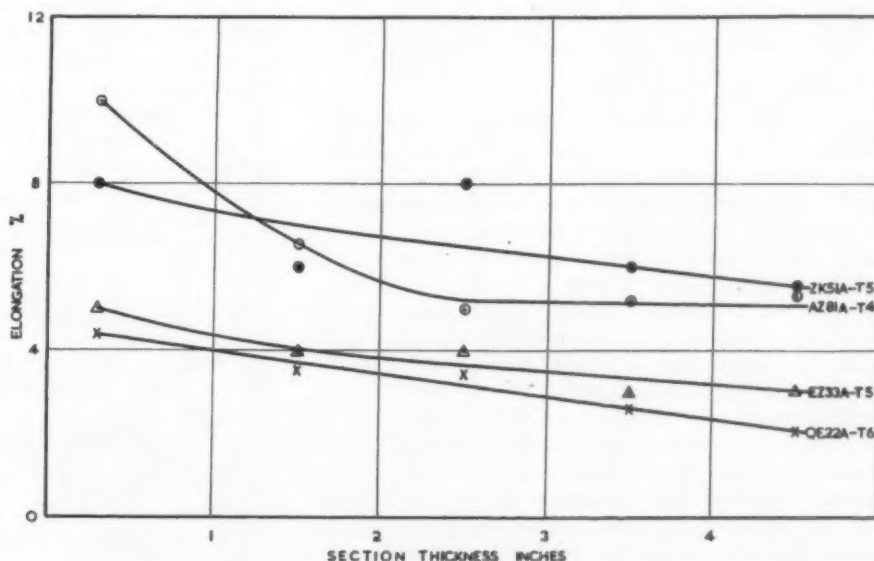


TABLE 14 — COMPARATIVE TENSILE PROPERTIES OF ONE IN. ROUND TEST BARS AND 4 IN. DIAMETER CYLINDERS

Alloy	1 in. Dia. Test Bar <sup>1</sup>			4 in. Dia. Cylinder <sup>2</sup>		
	0.1 % Y.S. 1000 psi	T.S. 1000 psi	E., % 2 in.	0.1 % Y.S. 1000 psi	T.S. 1000 psi	E., % 2 in.
MSRA	27.3	40.5	7.0	24.2	36.5	3.8
MSRB	28.4	39.2	5.2	25.3	33.6	1.0
ZH62A-T5	21.7	40.0	12.0	16.6	30.2	2.8
ZE41A-T5	20.8	33.1	5.5	17.0	26.0	1.8
ZK51A-T5	20.4	36.5	6.0	16.3	31.8	3.4
Al-4 1/2% Cu (C4A)	28.6	48.8	9.3	27.1	36.5	1.0

1. Values are mean of 3 results.

2. Values are mean of 5 results.

Consideration must hence be given, if the casting is in the T4 or T6 tempers, to the overaging effects of the preheat on the properties of the casting. Figure 5 shows that QE22A-T6 rapidly overages at 500 F (260 C). This, and the fact that the weld is in the as-cast condition, normally requires that the casting be fully heat treated after welding. Welds should be re-examined after heat treatment to ensure that minor discontinuities have not been opened up by the quenching operation.

The corrosion resistance of QE22A is generally similar to that of other magnesium base casting alloys. An important consideration where high strength alloys are concerned is susceptibility to stress corrosion. Tests by R. J. M. Payne and N. Bailey<sup>6</sup> have indicated that neither the normally heat treated nor overaged alloy is susceptible to stress corrosion. QE22A may be chromated and anodized by the normal methods applied to rare earth containing magnesium alloys.

### DISCUSSION

The differences in the levels of properties obtainable from QE22A-T6 and alloys like AZ81A-T5, HK31A-T6 and EZ33A-T5 are such that the alloy must be placed along with ZK61A-T6 in the high yield strength category. The latter alloy is however likely to give appreciably lower yield strength in many casting designs due to susceptibility to mass effect.

The excellent tensile properties at elevated temperatures have led to considerable interest in QE22A-T6 for aircraft and missile castings. There are also projected uses for long service applications where the good fatigue strength and creep properties at temperatures up to 400 F (204 C) are of importance. It may be said that QE22A is the most universal of magnesium alloys combining high yield strength at room temperature with attractive elevated temperature properties. The cost of QE22A alloy is comparable with that of the thorium bearing alloys HK31A and HZ32A.

The present trend of specifying premium grade for aircraft and missile castings with mandatory minimum properties on test bars cut from the casting presents a challenge to the magnesium sand foundry industry. The task of the alloy metallurgist is to provide not only materials with enhanced mechanical

TABLE 15 — COMPARATIVE TENSILE PROPERTIES OF ZK61A-T6 AND QE22A-T6 SEPARATELY CAST TEST BARS

Alloy	A.S.T.M. type bar <sup>a</sup>			British bar (BS2L101 form B) <sup>b</sup>		
	0.1 % yield, 1000 psi	Tensile, 1000 psi	E., % 2 in.	0.1 % yield, 1000 psi	Tensile, 1000 psi	E., % 2 in.
ZK61A-T6 <sup>c</sup>	29.3	45.2	5	23.7	39.0	3.5
QE22A-T6	25.5	38.0	3	24.8	37.8	4

a — 1/2-in. round cast to size.

b — 1 in. round, machined.

c — Solution treated 2 hr 932 F, air blast cooled, aged 48 hr 265 F.

TABLE 16 — DIDYMIUM CONTENT EFFECT ON INCIDENCE OF INCLUSIONS IN QE22A TEST BARS

Didymium, %	% of Test bars with inclusions (Total of 472 test bars)
1.0-1.49	0
1.5-1.99	9.5
2.0-2.49	18
2.5-3.00	25.5

properties, but also good castability so that gating development is not unduly protracted nor is excessive design simplification required before the necessary properties and quality standards are realized.

It has been an unfortunate corollary, and not confined to magnesium-base alloys, that some sacrifice in castability has been demanded when specifying high strength alloys. With QE22A the sacrifice has been minimized, and it is felt that the alloy merits its inclusion in alloy specifications and will be increasingly utilized for high strength, high quality, magnesium castings.

### ACKNOWLEDGMENT

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# ALUMINUM BRONZE HARD SPOTS

by Norman A. Birch

## ABSTRACT

Practically everyone in any way connected with aluminum bronze castings (whether ingot maker, foundryman or machinist) has at one time or another encountered an expensive defect known simply as "hard spots." These are unalloyed metallic inclusions near to diamond hardness, and range in size from barely discernible (but damaging even to carbide cutting tools) to as large as  $\frac{3}{8}$ -in. diameter.

While the nature, cause and cure of this defect is still a matter of speculation, the author reports detailed studies, including their microstructure and chemical composition and native habitat and is able to recommend inspection and shop procedures which virtually guarantee freedom from this particular defect.

## INTRODUCTION

Practically everyone in any way connected with aluminum bronze castings, whether ingot maker, foundryman or machinist, has at one time or another encountered an expensive defect known simply as "hard spots." Because they are troublesome to everyone, just about everyone has contributed in some measure to the ten-year compilation which is presented here in the form of quiz answers to the original "Twelve Questions About Hard Spots" project. At least six ingot makers have run independent tests, several crucible makers have yielded information they would normally have classified as trade secrets, melters and shop people have been most patient and understanding about the many records imposed on them in the early days, and the author's company's research center at Mahwah, N.J., has employed everything from a hand magnet to microchemistry to x-ray diffraction to help resolve the problem.

As of today, exactly what hard spots are is not known, nor is it known how to destroy them once they are formed. However, fortunately how to avoid them in melting operations and how to screen incoming ingot to keep them out of shops has been learned. This left the problem with the ingot makers. They in turn have been equally aggressive in attain-

ing good practices, so that hard spot ingot has not been seen at the author's company for almost 4 years.

## QUESTIONS AND ANSWERS

### *What are the hard spots?*

Hard spots are small silvery inclusions randomly located and intimately bonded in the metal. They are usually first noticed in machining because even a small hard spot is enough to chip the edge of a carbide cutting tool or break a tool steel hob. They can usually be picked out on a machined surface because there is a definite discontinuity in the finish where the tool was damaged by running into the hard spot. The visible hard spots range in size from small specks to as large as  $\frac{3}{8}$ -in. in diameter. Usually, the ones which cause damage to a tool are approximately  $\frac{1}{32}$ - or  $\frac{1}{64}$ -in. in diameter.

Hard spots can be readily identified by scratching with the point of a knife over the spot; unless the spot has been gouged out, the feeling is as though a shattered glass particle were embedded in the metal.

They are not to be confused with unalloyed metallic iron inclusions which are rare, random and soft. True hard spots are invariably round and occur in epidemics. The larger inclusions show definite flake-like structure, and spall readily with silvery fracture if attempt is made to chip them out of the base metal. Spalled flakes and the particles themselves are strongly magnetic.

On a polished micro specimen, a cross-sectioned hard spot shows up as a roughly round silvery inclusion cutting across both alpha and beta phases, and may or may not be attacked by the normal etch. Nearby may be small particles which appear to have either sloughed off or not yet agglomerated to the main inclusion. Still smaller particles of similar appearing inclusions will be in the matrix, which are the normal iron-aluminum intermetallic compound (also magnetic) found in aluminum bronzes. Figure 1 shows the cross-section of a massive hard spot, while Fig. 2 shows the internal components of another smaller and possibly more characteristic hard spot.

Figures 3 and 4 show the details of yet another hard spot. To avoid being misleading, please note

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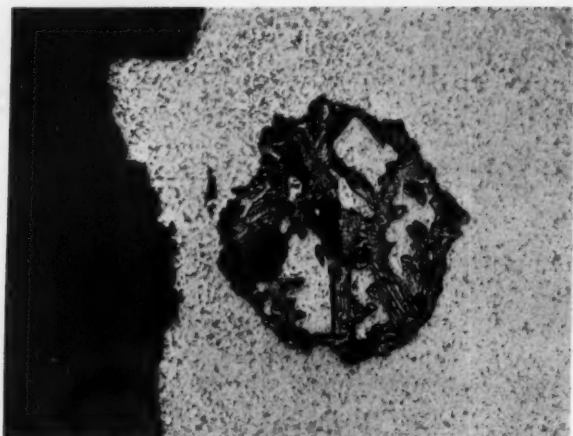


Fig. 1 — Massive hard spot. Notice essentially unaltered aluminum bronze structure within the inclusion although all hard spots do not show this. Concentrated nitric acid etch. 15 X.



Fig. 2 — Hard spot structure. Predominating speckled phase is 2400-2700 Vickers hardness, magnetic and is assumed to be iron rich. Small diamond shaped indications are micro hardness impressions. Micro Vickers hardness of individual phases (and colors, as-etched) are 790 (yellow), 946 (white), 1400-1700 (pink and magnetic), 2400-2700 (brown and magnetic). Concentrated nitric acid etch. Magnetism determined under separate magnetic etch. 500 X.

that Figs. 1 and 2 show "natural" hard spots found in defective castings, whereas the hard spots of Figs. 3 and 4 were characteristic of an "accidental" epidemic which developed during a laboratory investigation of the effects of boron as an alloying element to the aluminum bronzes.

#### Have any hard spots been analyzed?

Yes, the author's company has furnished natural epidemic hard spot samples to a number of interested sources and received the interesting answers shown in Table 1. It would appear that natural hard spots are not all the same, but are principally iron hardened by aluminum or small amounts of other elements.

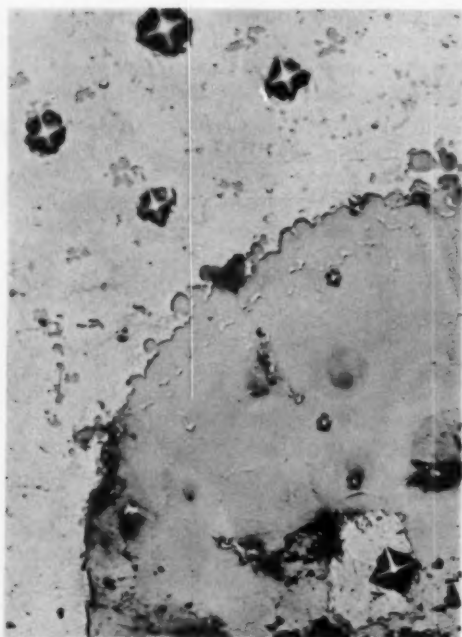
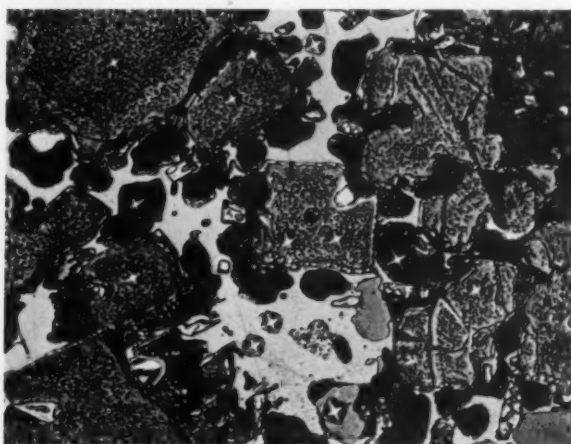


Fig. 3 — Unetched hard spot (gray). Note small indenter impressions (Vickers hardness 2700-3300) in hard spot compared to much softer aluminum bronze both surrounding and within the hard spot. 500 X.

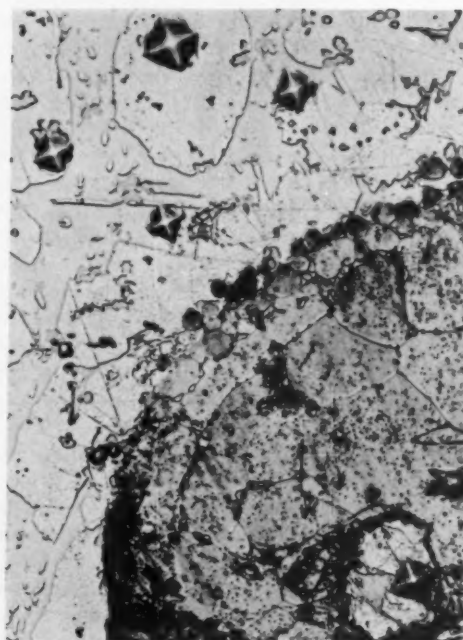


Fig. 4 — Same area as in Fig. 3, etched one sec in concentrated nitric acid to bring out aluminum bronze matrix phases of varying hardness. 500 X.

TABLE 1 — ANALYSIS OF NATURAL EPIDEMIC HARD SPOTS

Source	Method	Reported Composition
A	Microchemistry (sample of Fig. 2)	Quantitative: Iron 98.08 - 98.29% Carbon 0.84 - 1.09%
		Qualitative: Al, Ti, V positive Mo, Sn negative
B	Spectrographic	Approx. 75% Fe, 25% Al, no silicon, very little evidence of other elements.
C	Spectrographic	Approx. 98.5% Fe, trace Cr
D	Petrographic	70 - 80% Fe, balance Al, no silicon
E	Spectrographic	"An extremely high melting point alloy of iron, molybdenum, vanadium and titanium. Most remarkable is that unless the arc hit the hard spot, there are no indications whatever (less than 0.001%) of the presence of Mo, V or Ti."

***Is the occurrence of hard spots in aluminum bronze generally known in the industry?***

Yes, but it is treated like epilepsy and is generally not discussed except in the family, or with a specialist. Fortunately, the metallurgical specialists to both the ingot and foundry families are generally agreed that the source of most hard spots is faulty furnace practice. Certain crucible glazes, fluxes and certain grades of raw material are believed to trigger off an epidemic, but most epidemics can be traced to careless compounding of the alloy. The author's company has never had trouble from good ingot properly melted, even when hardeners have been used to modify the composition. However, hard spot castings have come from bad ingot properly melted, and from good ingot melted with shop borings, especially if pure metallic aluminum has been added to adjust the composition.

***Do hard spots segregate at the top or bottom of a melt of metal—might we get rid of them by skimming or decanting?***

Everyone agrees hard spots do not segregate. Their density, calculated from an assumed analysis of about 75 per cent Fe-25 per cent Al would be about 0.27 lb/cu in., which is about the same as that of the aluminum bronze base metal. Hence, they will not float nor be concentrated by centrifuging. They have been observed both on the outside and the inside of machined centrifugal castings, and are located randomly when seen in a fractured ingot.

***Can hard spots be located by nondestructive tests?***

The author's company has been unable to locate hard spots by nondestructive tests. At one time on hand were approximately 1000 rough machined rings weighing 16 lb each. By close visual inspection all suspect castings were culled out, often the only guide was a change in surface finish, since the spot which caused the tool damage which changed the surface finish was too small to be seen or had been machined away. Partial finish machining (and random fracture) showed that less than 10 per cent of the remaining 819 castings were from hard spot melts.

Unfortunately, no way was found to separate the good ones from the bad.

X-ray through a  $1\frac{3}{16}$ -in. metal section containing a visible hard spot approximately  $\frac{1}{32}$ -in. in diameter picked up the 0.030 in. jump in thickness caused by the tool hitting the spot but showed no trace of the spot, presumably because of similar density and intimate bonding.

The ultrasonic reflectoscopic inspection, which picks up discontinuities in structure and changes in modulus of elasticity, failed to give reliable evidence with either direct or angle searching units.

A magnetic analysis company reported the retentivity of the base metal as being too high to allow reliable location of the more magnetic but relatively small hard spots. Another company could offer no suggestions on locating other than exposed hard spots, most of which could be seen by eye.

***Has the analysis of the base metal anything to do with hard spots?***

Quite probably, but the effect of alloying elements is not certain. Knowing that hard spots are principally iron, it is believed there is statistically more chance of hard spot trouble when compounding the 5 per cent iron aluminum bronzes than when alloying the low iron (one per cent) grades. The author's company's main hard spot experience has been with Alloy 9C (A.S.T.M.-B148), since this is the general-purpose grade most commonly melted, but hard spot ingot from several sources in Alloys 9A (one per cent Fe) through 9D (4.5 per cent Fe) has been rejected. There appears to be no correlation with nickel in the range 0-5 per cent, and no hard spot trouble came from a single shop melt containing 2.0 per cent zinc or from others containing silicon up to 0.23 per cent.

Only the high manganese aluminum bronzes (nominal composition 75% Cu, 12% Mn, 8% Al, 3% Fe, 2% Ni) appear to be immune from hard spots. In common with aluminum bronzes these alloys are subject to a low-grade infection known as "sparkle" or "silvery needles" which is manifest in reduced ductility and a tendency for brittle fracture, on which the sparkle is readily visible to the trained eye. As will be discussed later, there is evidence that the sparkle is a hard brittle microconstituent similar to and possibly of the same generic origin as hard spots.

Add to this the knowledge that small amounts of manganese are beneficial to the strength-ductility ratio of aluminum bronzes and that small manganese additions have been helpful in destroying hard spots and it appears a reasonable hypothesis that sparkle can be treated as a mild case of the disease known as hard spots. No doubt it frequently passes unnoticed, except that test bar elongation values are a little lower than normal and tool regrind on machining is a little more frequent.

Manganese, therefore, appears to act as a possible vaccine against hard spots, and the combination of high manganese and low iron may explain why they have not been seen in the high manganese aluminum bronzes.

TABLE 2 — BORON TREATED ALUMINUM BRONZES

Heat No.	Analysis, %							
	Cu	Al	Fe	Ni	Zn	Sn	Mn	Si
53-682								
Tap 1	85.45	10.21	4.30	<0.01	<0.01	<0.01	<0.01	0.09
+FeB								0.036
Tap 2	85.81	10.27	3.92	<0.01	<0.01	<0.01	<0.01	0.09
53-633								0.015
Tap 1	88.32	10.26	1.30	<0.01	<0.01	<0.01	<0.01	0.08
+FeB								0.033
Tap 2	88.41	10.18	1.27	<0.01	<0.01	<0.01	<0.01	0.07
								0.029

### How do hard spots form?

Consensus among the metallurgical specialists who treat with this disease is that most natural epidemic hard spots are born during the exothermic reaction which occurs when aluminum is added to the bath. Normally, the nickel (if required) and iron have already been alloyed with the copper. The iron is frequently in the form of punchings which have been bundled, and the bundles are worked back and forth in hearth furnaces or are assimilated by the metal action of rotary furnaces. In local crucible furnaces the iron may have been added as nails or as core rods stirred in with a strap iron bar. In any event, circumstantial evidence indicates that the contagious moment is when the aluminum enters the bath.

If it finds unalloyed iron present, whether from the bundles, the nails or shreadings from an over-used overheated stirring rod, the conversion of soft unalloyed metallic iron appears to take place at exothermic heat and the melt succumbs to a case of hard spots or sparkle or both. It appears that the single best protection against these diseases is good stirring and adequate temperature and time to assure absolute assimilation of the iron before the aluminum is added. Shop remelts of straight aluminum bronze need watching too, since any free iron from overheated stirring rods, iron in contaminated borings, broken tool tips in partially machined castings, cleaning room shot or grit trapped in the riser cavities of remelt metal, or even the nails frequently used in aluminum bronze gating for skimming purposes and coming back in shop revert can be dangerous sources of free iron. This is especially true if the shop practice is to add a little metallic aluminum to compensate for melt loss.

There has been among the specialists a small minority who believed that hard spots were formed in the presence of silicon, and that 0.10 per cent was the maximum which could normally be tolerated, with 0.05 per cent a reasonable level and with 0.03 per cent a safe level. The data of Table 1 (at which time the author's company was much concerned with silicon) plus incidence of hard spots in ingot with silicon below the presumably safe level, combined with no trouble at high silicon (0.23 per cent), has pretty much dissipated the worries about silicon. Low silicon content is preferred, but there is no concern about the normal spread of 0.01-0.11 per cent silicon found in commercial aluminum bronze ingot.

Other commonly suspected sources of hard spots in foundry melting include:

- Worries about the use of silicon carbide as opposed to clay graphite crucibles.
- The glazes used by the crucible makers, especially the borosilicates or fluoborosilicates.
- The fluxes sometimes used as metal cover during melting, specifically the borides and fluorides.

While it is true that the worst case of hard spots came from a new silicon carbide crucible, with reportedly a silicate glaze on the inside, melting suspect ingot containing 0.12 per cent silicon, this same crucible later made perfectly beautiful metal when melting good ingot. No reason can be seen for taking advantage of the longer life of silicon carbide crucibles. Nor has trouble come from using new crucibles with presumably different glazes from several manufacturers.

**Fluxes.** The matter of fluxes is not quite so clear. As noted earlier, the laboratory developed an accidental epidemic of hard spots while investigating whether boron could be induced into the alloy merely by using a boric acid cover. The procedure was to melt 300 lb of metal under a boric acid flux, pour Tap 1 test castings; add 0.03 per cent boron as 18 per cent ferroboration to the remainder of the melt; pour Tap 2 test castings. The chemistries are reported in Table 2. Test bar properties are not reproduced because they varied randomly, depending on the number and location of hard spots within any given tensile specimen.

The type of hard spot encountered is the one shown in Figs. 3 and 4. The gray color (unetched) and the microhardness coincided exactly with a sample of 18 per cent ferroboration (unetched) mounted, polished and tested in a similar manner. It could be argued that these particular hard spots are merely remnants of unalloyed ferroboration, except that the melts obviously picked up boron from the flux alone, and hard spots and sparkle were found in all castings, both before and after the ferroboration addition. Other observations included:

- That the condition was more severe in both melts after the inoculation than before, although the boron content of Tap 2 castings is lower in both cases. Presumably the boron concentrated into hard spots, and the drillings for chemical sample failed to pick up a proportionate share of hard spots.
- That the condition was more severe with the high iron rather than with the low iron alloy.
- That another heat made with 3.0 per cent manganese had a sugary fracture rather than the characteristic sparkle or hard spots of the melts of Table 2.

### Are visible hard spots the only ones that cause trouble?

No. The hard spots big enough to be seen may cause tool breakage and can be cause for rejection of the casting, but the "invisible" ones can apparently cause excessive tool wear. This brings us to a more detailed consideration of the disease is termed silvery needles or sparkle, which it is believed could equally well be described as "invisible hard spots"

TABLE 3 — NICKEL ALUMINUM BRONZE INGOT, LOT 4555

	Composition, %									Bhn, 300 kg
	Cu	Sn	Pb	Fe	Ni	Zn	Al	Mn	Si	
Ingot 1	81.09	0.16	0.05	3.78	4.09	0.23	10.58	0.03	0.02	217
Ingot 2	81.08	0.12	—	4.16	4.08	—	10.45	0.07	0.03	212

Ingot 1 had fine fibrous fracture.

Ingot 2 had fine fibrous fracture containing sparkle.

Fractures of each ingot are representative of many fractured from this lot, and while vendor claimed all metal was from same melt, the differences in tramp elements and in fracture would indicate the lot to have been a mixture of two similar melts, one with sparkle trouble, the other without.

or "hard spot needles." These are shown in Figs. 5 and 6. Of a number of photographs and micros available, Fig. 5 was selected as representative of natural sparkle received in commercial ingot of the chemistry shown in Table 3, and Fig. 6 as typical of accidental sparkle developed in the boron treated melts of Table 2 and visible in the same fracture as the hard spot of Figs. 3 and 4. Micros of natural sparkle correlate closely with Fig. 6, and in all cases the needles appear to be different from and much larger than the normal Fe Al constituent found in well-dispersed small particles in all iron-containing aluminum bronzes.

Recognizing that the sparkle constituent is harder and larger than the normal microconstituents, and that it can influence machining, and that it is a melt characteristic (although less evident than hard spots), sparkle ingot is avoided as much as possible. Usually this is a choice of source.

#### *Do the hard spots affect mechanical properties and casting serviceability?*

Yes, but not seriously. The costly nuisance of hard spots is tool wear and breakage on machined parts. Castings to be used unmachined, or with only one surface faced and a few holes drilled into a flange, are equally as strong and satisfactory with or without hard spots. Even when the spots appear on a machined surface, they are so few, so random and so intimately bonded within the base metal that they do not lessen serviceability of the casting. Justification for this view is based on many tensile test results where spots found in the fracture had not appreciably altered the expected test bar values unless they occurred at or close to the machined surface of the bar, in which case yield strengths were normal but the elongation and ultimate strength values were considerably reduced. Only on critical surfaces, such as the bore of a bushing where they might score the shaft, would hard spots be significant cause for rejection.

Sparkle can be more serious, as shown in Table 4. The comparison is especially interesting because the British and American data were developed independently, and both were the result of a distinct fracture characteristic noticed by ever-curious trained metallurgists (this kind of detective work can be endlessly fascinating). It has been called "silvery needles," the British called it "sparkle," which term has been



Fig. 5 — Sparkle fracture (silvery needles) of aluminum bronze ingot no. 2 (lot 4555). Microhardness of needles averaged 450 Vpn compared to matrix average of 235 Vpn. 50 X.

elected to use as being simpler and equally descriptive. Note that the yield and tensile are not significantly affected, but that sparkle reduces the elongation and (according to the British) is even more detrimental to impact. Care should be used in extrapolating these data for purposes other than this comparison since these are averages, and both aim-



Fig. 6 — Hard spot needles in boron treated aluminum bronze. 500 X.

TABLE 4 — SPARKLE EFFECT ON MECHANICAL PROPERTIES

	Heat Treated 2% Nickel Aluminum Bronze (A.S.T.M. B148, Alloy 9C-HT)			As-Cast Alloy 40	
	Required	Normal	Sparkle	Normal	Sparkle
Yield					
Strength, psi*	40,000 min.	48,000	49,000	46,500	47,000
Tensile					
Strength, psi	90,000 min.	104,000	102,000	100,500	98,000
Elongation, % in 2 in.	6 min.	16	10	34	29
Izod Impact, ft-lb	—	—	—	31	19
Source:	American Brake Shoe		J. Stone Co. (England)		

\*Yield at 0.5% extension for American values; at 0.15% offset for British values.

chemistry and the degree of sparkle will affect the average properties.

The British, for example, report another comparison where elongation dropped from 32 per cent normal to 24 per cent with sparkle present. The author's company has, in turn, had rejections because sparkle cut the elongation below the 6 per cent passing figure. Sparkle can be more dangerous than hard spots, although it is a milder disease and less apparent, because it can steal away the safety factor while still permitting test bars to pass requirements. One consolation, however, is that direct comparison between sand cast keel blocks and test bars cut from a similar section thickness centrifugally cast in a metal mold indicates that rapid cooling tends to suppress sparkle.

#### Can hard spots be destroyed by remelting?

Not by ordinary remelting, at least. If they are an iron-aluminum compound they would have a melting point above 2600 F, and aluminum bronze is normally melted to a maximum of 2200 F. Some of the specialists claim that remelting merely causes hard spots to grow, and that the only safe practice is to run the contaminated metal through a cupola, burn-

ing out all the iron and aluminum, to salvage the copper content only.

Figure 7 shows two lots of fractured hard spot ingot, one with sparkle condition in addition to the hard spots. To run a definitive test, from Lot 3448 28 ingots at random were broken (about 500 lb). All were found to have sparkle fracture, with 14 ingots (or 50 per cent) having visible hard spots. The metal was crucible melted without flux or additions to 2550 F, with sample ingots poured off at intermediate temperatures of about 2150 and 2250 F and the balance pigged at 2550 F. All ingots were fractured. The low temperature ones were excellent with no trace of hard spots, but the others varied from excellent, to some with sparkle and one with a beautiful  $\frac{1}{8}$ -in. diameter ball on a  $\frac{3}{16}$ -in. diameter shell of what appeared to be the same material. The condition was a sphere within a sphere, as though the outer one had grown around the inner one. The microchemistry reported in Table 1 is that of the outer sphere; the ball was the subject of Fig. 2.

In yet another remelting test 500 lb of 40 per cent visible hard spot ingot were melted to 2600 F, adding a small amount of aluminum to compensate for expected melt loss. All ingots were fractured and none showed any evidence of hard spots. Standard keel block test bars met the requirements and the metal was used, but the fracture of both the ingot and the test bars showed a trace of sparkle and one test bar had one small hard spot.

One vendor asked for minor chemical deviation in order to rework and resubmit five lots of rejected alloy 9C ingot. He remelted each lot separately, deliberately stirring in 0.5 per cent manganese. Three lots cleared up and were accepted, the other two still had hard spots. Melting to high temperatures with or without a manganese addition may be helpful, or may not be helpful.

#### Can we protect against hard spots by inspection of ingot?

Yes, definitely. The author's company has not experienced a single case of unexplained hard spots since 1951. The closest to it was while melting sparkle ingot in the shell molding department. Hard spots were found in one or two melts, and for a few days there was concern that sparkle alone could degenerate into hard spots, something never experienced. Soon, however, traces of hard spots appeared in centrifugal castings and also in the mechanized department castings, each of which had their own melting furnaces and were using different ingot.



Fig. 7 — Fractured hard spot ingot (alloy 9C). Lot 3448 (left) shows sparkle fracture with one hard spot at upper right. Lot 3840 (right) shows four hard spots in a five fibrous fracture.

Fig. 8 — Fractured good ingot (alloy 9C). Both lots show uniform fine grained fracture free of any defects or inclusions.

Investigation showed that the only raw material common to all three departments was one batch of shop borings, and the company prefers to believe that circumstantial evidence convicted the shop borings of somehow being contaminated rather than to take this single instance as evidence that sparkle can actually agglomerate to produce hard spots, or that our ingot receiving inspection procedures are not fool-proof.

The ingot receiving inspection is simple, inexpensive and fast, if you have a suitable hydraulic press. Ingot is purchased to A.S.T.M. B30, which requires each lot to be uniform, to be of one melt only and to be so identified. Random samples are selected in the ratio of one ingot for each 1000 lb of metal. These are fractured under the press. Figures 7 through 11 show representative fractures of a number of ingot, with and without defects. Next, one-half of each ingot is spot ground on the bottom face to clean metal and is checked for hardness.

If the fractures are uniform in appearance and contain no unalloyed metallic inclusions, the hardnesses are uniform within 14 Bhn points spread, the hardnesses are within the range established as proper for the alloy, the vendors certification shows chemistry and properties within specification and the vendor is known from past experience to be reliable, then the ingot is accepted and used without further question. For a normal lot of 10,000 lb, the receiving clerk can clear the ingot for use in less than 30 min. If the fracture is nonuniform in appearance, if the hardness varies more than 14 points within the lot or is out of the expected range, it usually indicates improper alloying or inadequate mixing before ingotting and a metallurgist takes over. Figures 12 and 13 show representative fractures.

Note that fracture and hardness are not purchase requirements, nor is ingot rejected for any cause other than nonuniformity or out-of-specification. Fracture and hardness are merely quick and inexpensive inspection tools to insure good raw material for the casting quality requirements of these premium alloys.

This is not to say that all ingot not to the above tight inspection standards is rejected. As long as the



Fig. 9 — Fractured good ingot (alloy 9C). Lot 3997 (left, 170 Bhn) has coarse woody fracture. Lot 4003 (right, 179 Bhn) has fine woody fracture).



Fig. 10 — Fractured good ingot (alloy 9C). Lot 4330 (left) has coarse woody fracture. Lot 4331 (right) has columnar woody fracture.

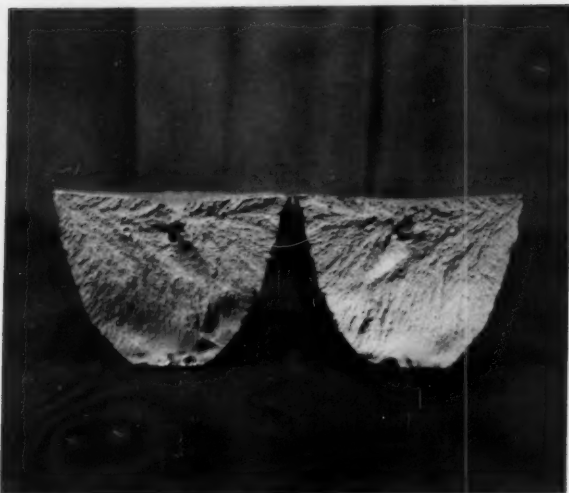


Fig. 11 — Fractured hard spot ingot (alloy 9C). One ingot (lot 3441) showing one large hard spot.



Fig. 12 — Fractured nonuniform ingot (alloy 9C). Lot 3999, fine grained, 143 Bhn (left) and coarse grained, 241 Bhn (right).

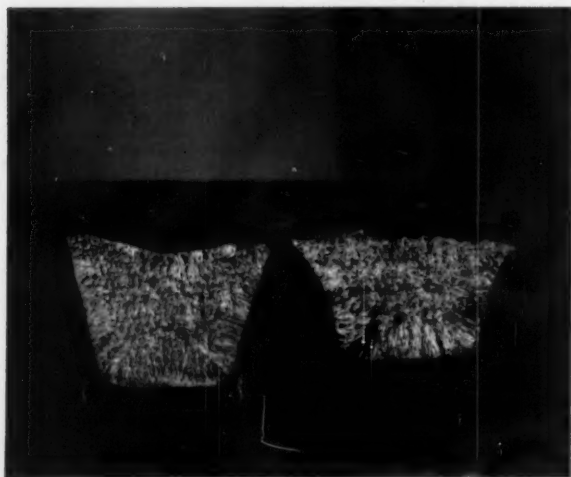


Fig. 13 — Fractured nonuniform ingot (alloy 9A). Lot 4721A, silvery crystalline, 302 Bhn (left) and tough bronzy, 115 Bhn (right).

ingot is uniform, and within a reasonable hardness spread of approximately 20 points, the metallurgist will accept and can blend uniform lots of high and low hardness to provide a proper average alloy for melting. He can even use an occasional nonuniform lot, provided the nonuniformity is not excessive and his required melt weight will use up the entire lot, permitting it to properly homogenize on remelting. However, he cannot use a mixed shipment of five 4,500 lb melts unidentified, one of which contained hard spots.

Nor can he use a 27,000 lb melt of manganese bronze which was clean enough but varied in copper content of individual ingot from 56 to 72 per cent (this was discovered under the press when some ingot broke like glass and others would only bend). For the foundry to try to select material for a 600 lb melt from this lot of ingot would have been sheer folly. All ingot sources have been most cooperative and helpful in eliminating this type of shipment, and many are now using the hardness check as a quality control on the ingot line.

#### *Are hard spots encountered in other copper-base alloys?*

Yes, the high tensile yellow brasses (commonly called manganese bronzes) experience some of the same difficulties as the aluminum bronzes, since they also contain appreciable iron with aluminum contents up to 6.5 per cent. Some manganese bronzes will exhibit a bright sugary fracture, but never sparkle. There will be occasional unalloyed metallic inclusions, but these are usually a few flakes of unalloyed iron, an occasional ball of metallic-appearing slag (usually immediately under the top surface) or a small spalled piece of ingot mold, but never a true epidemic hard spots of the type described for aluminum bronzes. In fact, manganese bronze ingot has never been rejected for inclusions, recognizing that they will slag off or be assimilated on melting. However, ingot sources are kept advised, since they also are interested in promoting and maintaining a quality reputation for these most important alloys of the copper-base castings industry.

# CO<sub>2</sub> PROCESS IMPROVEMENTS

by D. A. Taylor

## ABSTRACT

Consideration of the mechanism of bonding in the CO<sub>2</sub> process using silicates of different SiO<sub>2</sub>/Na<sub>2</sub>O ratio indicates that with low ratio silicates, the molding mixture can tolerate considerable amounts of impurities which are usually regarded as harmful. Subsequent work showed that the presence of clay reduces strength after gassing by only a moderate amount, and where necessary this can be overcome by a small increase in the amount of silicate added.

Clay, or any material containing alumina, reduces the rate of conversion of quartz to cristobalite at high temperatures, and hence the rate of expansion, and reduces metal penetration and the risk of spalling. Burnt clay is as effective as raw clay and has the advantage that it does not make ramming difficult, and mixtures of undried silica sand and burnt sand from a green sand system can be used to replace the dry silica sand in general use.

Clay also affects strength on cooling from high temperatures, and reduces the difficulty in removing cores from castings of moderate size. Mixtures of new silica sand and sand recovered from silicate bonded molds by crushing only are also being successfully used. For reducing the spalling and growth of silicate bonded ladle linings, the use of 4 per cent alumina is more satisfactory than the addition of clay.

The gassing operation can be improved by using a mixture of equal amounts of air and carbon dioxide.

## INTRODUCTION

The CO<sub>2</sub> process has two advantages which have been the chief cause of its success:

1. The mold or core can be hardened in contact with the pattern, or core box, and an accurate reproduction is obtained.
2. Hardening is rapid at room temperatures and drying stoves are unnecessary. Transport to and from the stoves of molds which require a crane for lifting is frequently a source of trouble, particularly in the jobbing foundry, and a reduction in the

number of times molds have to be moved is of great advantage.

The process as used at the present time has these disadvantages:

1. It is difficult to remove cores from some castings.
2. Metal penetration resulting in poor surface finish and sometimes spalling of the mold surface occurs, particularly with large molds.
3. Large quantities of dry silica sand are required and similar quantities of used sand have to be discarded. Recovery of the used sand is possible only by the use of a difficult cleaning process.

The object of this paper is to show that by proper selection of sand and silicate, core removal can be made somewhat easier, surface finish can be improved, the amount of new silica sand required can be reduced and in some cases undried can be substituted for dried silica sand. Gassing can be improved by using mixtures of carbon dioxide and air in place of carbon dioxide alone.

## NATURE OF THE SILICATE BOND

Soda and silica can be combined in any proportions, and the resulting compounds are miscible with water. The range of possible silicates is shown in Fig. 1.

The silicates commercially available have a silica/soda ratio between 3.3 : 1 and 1.6 : 1, with a water content between 40 and 60 per cent, and are covered by the shaded area in the graph.

When the silica/soda ratio exceeds 3 : 1, the silicate is unstable and is rapidly decomposed by carbon dioxide with the precipitation of silica, as seen in Fig. 2. When these silicates are used in the CO<sub>2</sub> process, gassing is extremely rapid, but the precipitated silica has poor bonding properties and gassed molds are weak and friable.

When the silica/soda ratio is reduced to 2 : 1 the effect of carbon dioxide is to form sodium carbonate and a silicate of higher ratio. At the same time water is removed from the silicate and viscosity increases rapidly with a resulting increase in strength, as shown in Fig. 3. The gassing period needed is longer and, if

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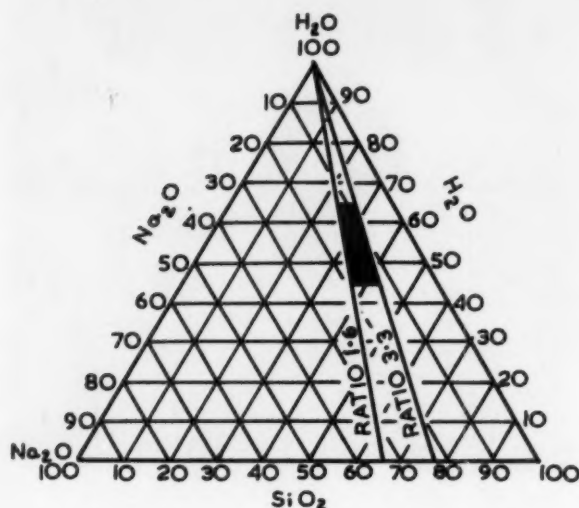


Fig. 1 — Composition triangle showing field of sodium silicates available for foundry use.

this is interrupted and a mold containing silicate dried, there is a further increase in strength, as shown in Fig. 4, since sodium silicate itself has a powerful bonding action. If, on the other hand, gassing is continued the silicate is completely decomposed and the mold becomes weak and friable.

When the silica/soda ratio is still further reduced, gassing time is vastly increased and silicates of this kind are rarely used with pure silica sand.

In practice, three types of bond may be present:

1. Precipitated silica. This is relatively weak and with normal additions of silicate, strength rarely exceeds 100 psi.
2. "Setting" following alteration of silicate ratio and increase in viscosity. This gives strengths of up to 300 psi.
3. Drying of unaltered silicate. This gives strengths exceeding 1000 psi.

In general, the lower the silicate ratio, the longer is the time required for gassing, but the higher the strength of the gassed mold.

#### STRENGTH WITH GASSING TIME 3:3:1 RATIO SILICATE

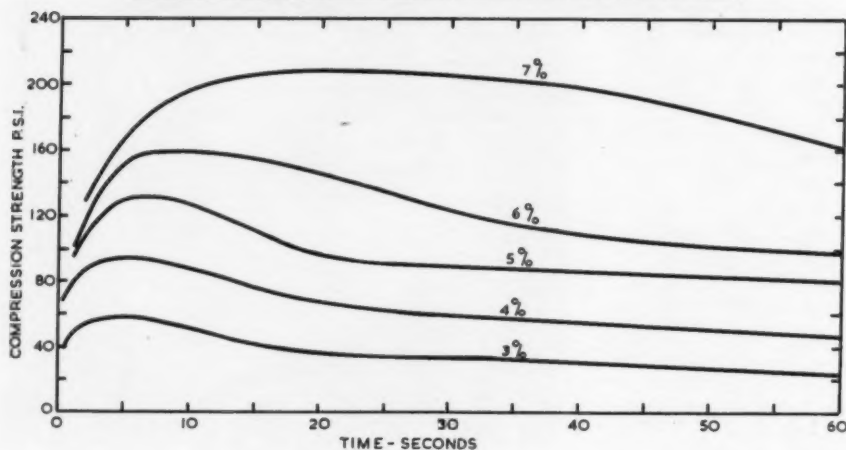


Fig. 2 — Strength with gassing time for 3.3 : 1 ratio silicates.

Fig. 3 — Strength with gassing time for 2 : 1 ratio silicate. Silicate addition — 4 per cent.

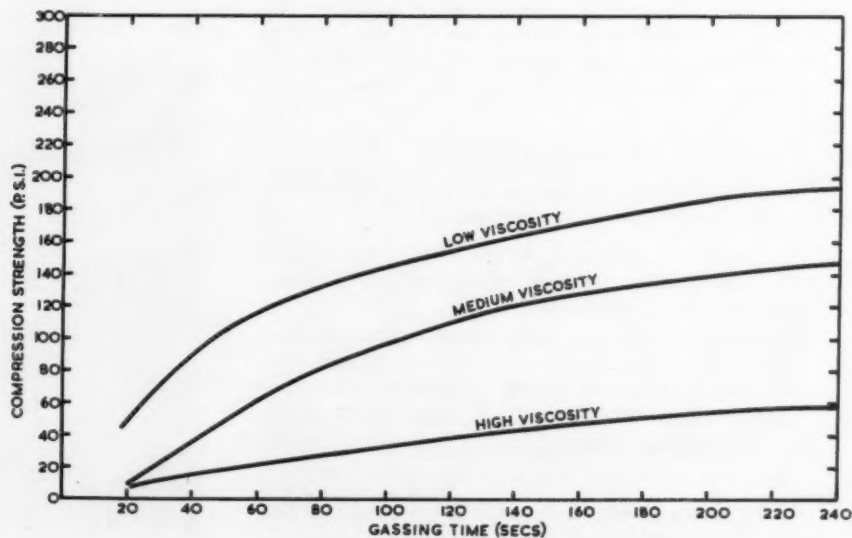
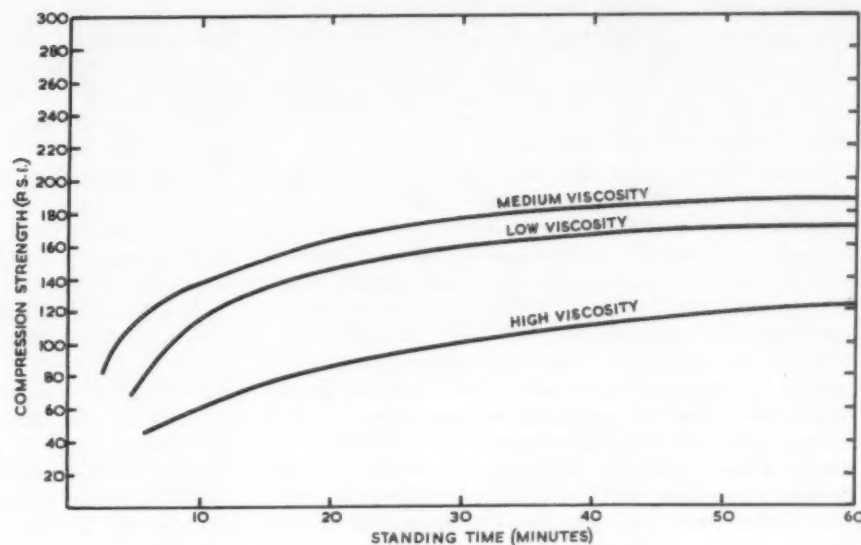


Fig. 4 — Strength with standing time for 2 : 1 ratio silicates. Silicate addition — 4 per cent. Gassing time — 30 sec.



#### Water Content Effect

The rate of increase in strength on gassing is greater with silicates of lower viscosity, i.e., higher water content. The long gassing time required with the silicates of low ratio can therefore be offset by increasing the water content.

#### Clay Effect

When the base sand contains a small amount of clay the gassed strength is reduced, but the reduction is small and can readily be counteracted by a small increase in the amount of silicate. In consequence, attempts have been made to use sands containing up to 2 per cent of clay and fines in place of purer sands, which were more costly and difficult to obtain. There is no technical difficulty in this, and the cost of any additional silicate required was more than offset by the inexpensiveness and convenience of a local sand deposit. However, the dust produced in drying sand containing up to 2 per cent of clay and fines caused so much nuisance that the practice was abandoned.

If the clay content is raised appreciably two changes occur:

1. Water is transferred from the silicate to the clay and the mixture appears dry. Gassed strengths are then low.
2. Any exchangeable bases in the clay may react with the silicate and change the silica/soda ratio.

There does not seem to be any difficulty in taking care of these effects of clay; the first can be overcome by adding water or, better, by using undried sand, and the second by using the silicate with a ratio of 1.6 : 1.

In order to examine the possible fields of use of clay-bearing sands, mixtures of Erith silica sand and Bromsgrove clay-bonded sand were made in various proportions and bonded with 4 per cent of 1.6 : 1 ratio silicate. Erith silica sand is a clay-free sand mainly on the 60 and 100 mesh sieves; Bromsgrove sand has a wide spread of grain size below 60 mesh and contains 12 per cent clay. Standard test pieces were prepared

and gassed for one min with gas passing at the rate of 10 litres/min.

Test pieces were tested immediately after gassing and also after standing on the bench for 24 hr. The test results are shown in the table.

PROPERTIES OF MIXTURES OF NEW SANDS

Sand Mixtures			Green Properties			
Erith, %	Bromsgrove, %	Gassed Strength	Strength after 24 hr	Moisture, %	Permeability No.	Green Strength lb/sq. in.
100	—	< 30	278	1.7	268	0.9
80	20	106	455	2.1	180	2.4
60	40	133	175	2.4	116	5.6
40	60	92	103	2.8	70	8.6
20	80	90	100	3.8	45	10.7
—	100	75	70	4.5	34	13.0

These tests illustrated the field of use and limitations of clay-bearing sands and low ratio silicates.

In the absence of clay the normal gassing procedure had little effect, and although strength developed on standing this was due to drying. If this test piece had been dried in a stove or allowed to stand until dry, its strength would have exceeded 1000 psi.

As clay-bonded sand was added in increasing quantity, gassed strength rose to a maximum with 40 per cent clay-bonded sand, and then fell, but even with clay-bonded sand alone the gassed test pieces were not unduly friable.

Strength after standing for 24 hr reached a high maximum with 20 per cent clay-bonded sand, and then fell. Whenever the proportion of clay-bonded sand exceeded 50 per cent strength changed only slightly on standing after gassing.

Sodium silicate increases the toughness of a clay-bonded sand, and all mixtures containing more than 60 per cent of the naturally bonded sand had a shatter index of 100. These would be too tough to ram

readily with any conventional molding machine. The upper limit of clay content permissible is therefore determined by the toughness of the molding mixture, and not by the properties after gassing.

#### High Moisture Content Effect

In the test reported in the table, the moisture content was so adjusted as to give a mixture which could be molded with the least difficulty, since molds are sometimes stripped in the green state and gassed later. However, much higher moisture contents can be tolerated, and sands containing up to 10 per cent have been used to produce sound molds after gassing.

In an extreme case, a foundry system sand containing 10 per cent water and 5 per cent low ratio silicate was used to make molds for heavy brake drums. With this moisture content, the sand resembled the loam used for sweeping up rather than a normal green sand. After gassing the mold was firm and was poured immediately. Unexpectedly, there was no undue turbulence during pouring and no unusual evolution of gas, and the castings produced were perfectly sound.

When, however, sands with high moisture content are gassed and allowed to stand, a white deposit forms on the surface which becomes extremely friable. On prolonged standing the mold surface may fall away. This is illustrated in Fig. 5, which shows test pieces from a natural sand containing 8 per cent clay and fines, 10 per cent water and 5 per cent silicate. *A* is a test piece shortly after gassing, and *B* after standing 24 hr.

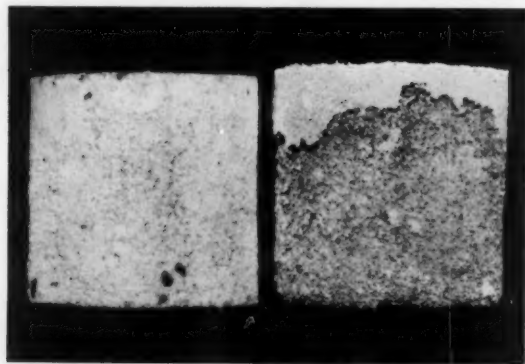


Fig. 5—Effect of standing on silicate bonded sands of high moisture content. *A* (left) and *B* (right).

On this account it is recommended that the moisture content of the sand before silicate addition should not in general exceed 3 per cent.

#### THE CO<sub>2</sub> PROCESS IN THE GREEN SAND FOUNDRY

It has been shown that sands containing clay can be used in the CO<sub>2</sub> process, and the way is therefore open to make use of the discard from the green sand system. This consists of clay-bonded sand which has lost some of its bonding power as the result of

being heated by molten metal. Some of this sand is almost unchanged and some has lost all its bonding power, and it is necessary to establish a means of taking care of any variations between these extremes.

A sample of system sand returning to a mill in a green sand foundry was taken as the type of sand having the highest amount of active clay, and sand which fell from hot castings as having the lowest. Sand removed from any part of the system would have properties in between these two, and if a method was devised which could be used successfully with either, it would take care of any sand from the system.

The system sand was synthetic, and on milling with water had a green strength of 10 psi, a shatter index of 80 and a permeability of 90. It contained 4 per cent of sea coal. The dry sand was mixed with 3 per cent water, and 5 per cent low ratio silicate was added. This raised the shatter index to 100 and made ramming difficult. After gassing the molds were satisfactory, having a gassed strength of 130 psi rising to 180 psi on standing for 24 hr.

It would not have been possible to ram molds satisfactorily by normal methods, and few foundries have the equipment for dealing with it successfully. Accordingly, the dry system sand was mixed with an equal amount of undried silica sand to give a moisture of 2.5-3.0 per cent, 5 per cent silicate was added, giving a shatter index of 60, which could be molded without difficulty, and the gassed strength obtained was 200 psi.

The sand which had been strongly heated was satisfactory for use either with or without the addition of silica sand. It would be possible, by selection of the discard, to use the process without new sand, but it is safer to adopt the method which is successful with any sand from the system.

Undried silica sand as delivered to the foundry usually contains less than 6 per cent water, but occasionally when quarried in wet weather or delivered straight from a washer, the water content may be higher. If, however, the sand is allowed to stand in a bunker, or slightly heaped up, drainage will soon reduce the water to below 6 per cent.

The use of a mixture of used clay-bonded sand with undried silica sand and low ratio silicate is particularly advantageous in the small or medium sized foundry in which the bulk of the production is in green sand molds, the CO<sub>2</sub> process being used for some cores and difficult molds. Not only does it enable sand which is unsuitable for use in the green sand system to do another job before it is dumped, but it does away with the need for drying quantities of silica sand which is dusty as well as costly.

#### Gassing Procedure

The hardening of silicate molds is due to a chemical reaction which, for a silicate of given composition, proceeds at a rate depending only on temperature, provided that CO<sub>2</sub> is present. The ideal method of gassing would be to supply gas to all parts of the mold or core at the same time, and at a rate sufficient to replace that used in the reaction. If gas is supplied at a faster rate than this it fulfills no useful purpose and simply escapes to atmosphere.

Applying gas in the ideal way is impracticable. Temperature changes considerably during the day, but it is unlikely that either maintaining a constant sand temperature or matching the gassing rate to the temperature would be worth while. The only exception to this is when the temperature of the sand falls low, as may happen after a shut-down in winter, when occasionally the sand is so cold that the reaction does not take place (a small percentage of really warm sand in the mix takes care of this difficulty).

It is also impracticable to bring the gas to all parts of the mold at once, and in foundries using the  $\text{CO}_2$  process exclusively it may be worth while to develop special techniques for gassing, but the most widely used method is to introduce the gas at a few points. If the gas is introduced rapidly much of it escapes, whereas if the rate is greatly reduced hardening is uneven, being complete at the points of entry before any great change has taken place elsewhere. By diluting the gas with an equal volume of air, more uniform gassing can be obtained without excessive wastage. Suitable proportioning valves are required.

Displacement of the air in the mold pores by gas is easier and proceeds over a larger part of the mold as permeability rises, and on this account it is desirable that the permeability of the sand should exceed 40, but most molding sands when mixed with an equal quantity of silica sand have a permeability well in excess of this figure. However, sands containing sand from a green sand system usually have a lower permeability than silica sands, and dilution of the gas is desirable. Moreover, the reaction proceeds more slowly with low ratio silicates, and the two factors of gassing rate and permeability combine to make the use of an air/ $\text{CO}_2$  mixture desirable if excessive wastage is to be avoided.

#### SILICATE-BONDED SANDS DURING HEATING AND SUBSEQUENT COOLING

##### *Properties at High Temperatures*

When silicate-bonded clay-free sands are heated, strength rises as a result of complete drying of any

undecomposed silicate, and reaches a maximum at about 400 C (752 F). Strength then begins to fall and is negligible at temperatures exceeding 700 C (1292 F) when the bond is almost completely liquid, as shown in Fig. 6. If heating is continued at really high temperatures the silica sand itself changes. Quartz, the usual form of silica, is stable at temperatures up to 870 C (1598 F), when it changes to tridymite, which in turn changes to cristobalite above 1400 C (2552 F). These changes are, however, extremely slow and rarely occur to any great extent in molds, although small amounts of tridymite have been found in the sand adhering to the surface of large steel castings.

It would be expected that the presence of a fusible silicate would increase the rate of change and reduce the temperature at which it occurs, but the extent of the influence was unexpected. If a silicate-bonded silica sand is heated to a temperature exceeding 1000 C (1832 F) for half an hour or so it changes completely to cristobalite, the tridymite stage being almost completely missed.

Quartz has a specific gravity of 2.65 and cristobalite of 2.32, and the change is therefore accompanied by an expansion. The effect of heating standard test pieces for 20 min at various temperatures can be seen in Fig. 7. What happens is not clear. The fall in specific gravity should lead to an increase in volume of a little over 12 per cent, but the test piece on the right of Fig. 7 has increased in volume by more than 30 per cent. Cristobalite can be found on the surface of molds which have been used for the production of castings of quite moderate size and there are indications that surface finish may be affected.

##### *Metal Penetration and Surface Roughness*

Metal penetration and surface roughness are frequently more pronounced on silicate-bonded sands than on clay-bonded sands of the same grain size. It is possible to slow up the change to cristobalite by the addition of a number of substances, particularly those containing alumina. Clays are effective to a considerable extent, but alumina alone has an even more pronounced effect, and almost completely inhibits the change.

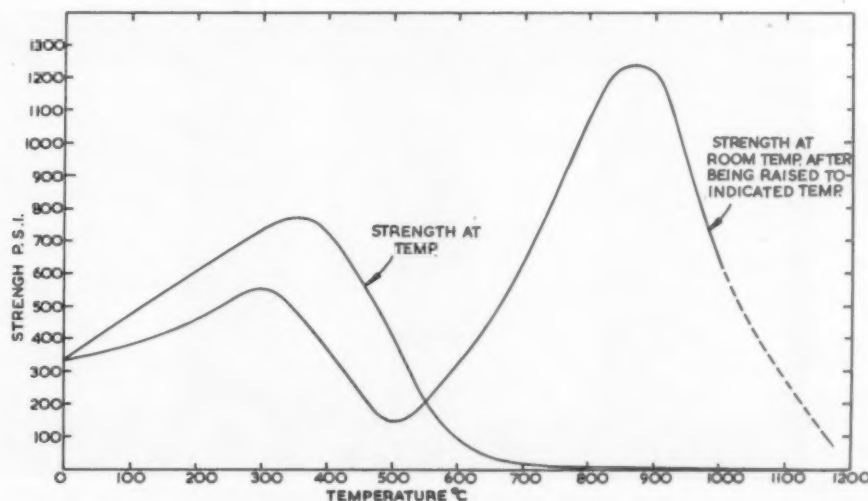


Fig. 6 — Strength of  $\text{CO}_2$  process material at and after cooling from high temperatures. Four per cent silicate.

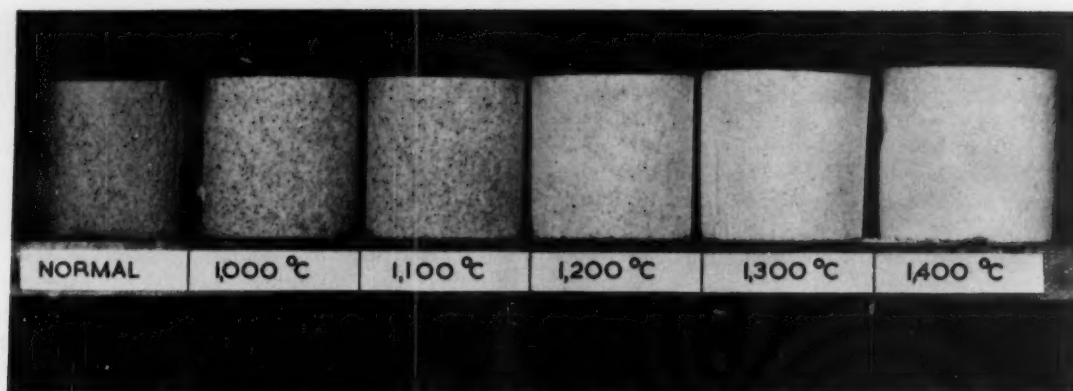


Fig. 7 — Expansion of silicate bonded sand at temperatures above 1000 C (1832 F).

It appears reasonable to suppose that metal in close contact with sand shown at the right of Fig. 7 would have a rougher surface finish than when in contact with that on the left, but it is not so obvious that an expansion of the surface layer could lead to larger pore spaces unless the dimensions of the mold increase. If the mold remains constant, it appears that an increase in the volume of the grains could only be obtained by a reduction in the size of the pores, and an improvement in surface finish. Nevertheless, surface finish is improved by an alumina addition and this technique is being used successfully in some foundries.

Clay itself has a similar effect and on this account an improved surface finish is obtained when using clay-bearing sands with low ratio silicates, even when permeabilities are similar. Since the system sand usually contains a certain amount of fines other than clay, there is a still further improvement in surface finish, and it may be possible to dispense with alcohol-based coatings for deep castings.

The effect of certain additions on the expansion is shown in Fig. 8. Alumina has a much more pronounced effect, which persists even when the sand is heated at 1400 C (2552 F) for 30 min. Test pieces

containing 0, 1, 2, 3 and 4 per cent alumina after this treatment are shown in Fig. 9.

#### LINING LADLES

An interesting use of the CO<sub>2</sub> process is in the lining of ladles. Silicate-bonded sand is easy to apply and is readily hardened, and provided that prolonged heating in an inverted position is avoided, a good firm lining is obtained which remains cleaner than a normal brick or sand-lined ladle during use. However, the high expansion may result in either spalling in the early stages or growth subsequently, and when such a lining was used for quite a small crucible it projected an inch beyond the crucible edge after short operation. The addition of 4 per cent of alumina eliminated both spalling and growth and the lining was satisfactory. There may be an upper limit of ladle size beyond which it is not safe to use silicate-bonded linings, but this limit is not known.

#### STRENGTH AFTER COOLING — CORE BREAKDOWN

When a silicate-bonded core is heated its strength both at temperature and on subsequent cooling increases as a result of drying of any unchanged silicate present. When the heating temperature is raised

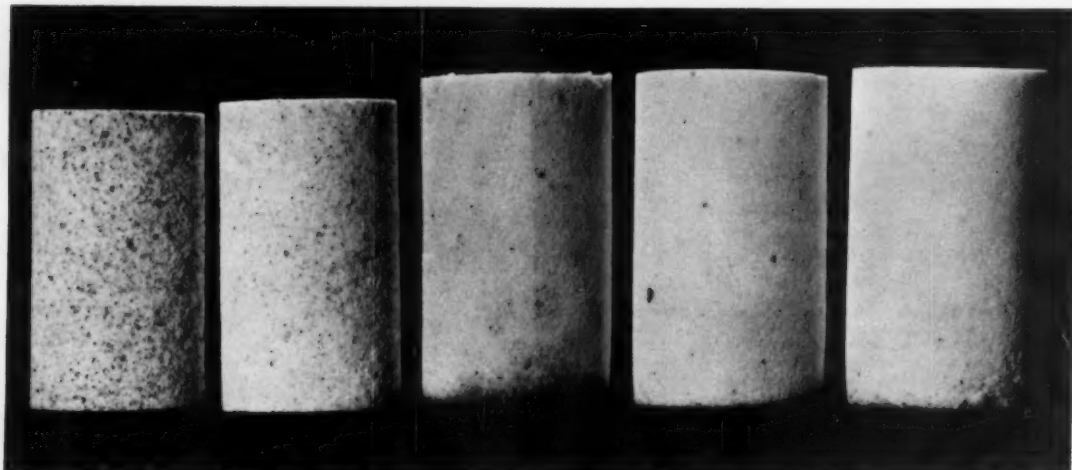


Fig. 8 — Effect of additions on silicate bonded sand at 1400 C (2552 F).

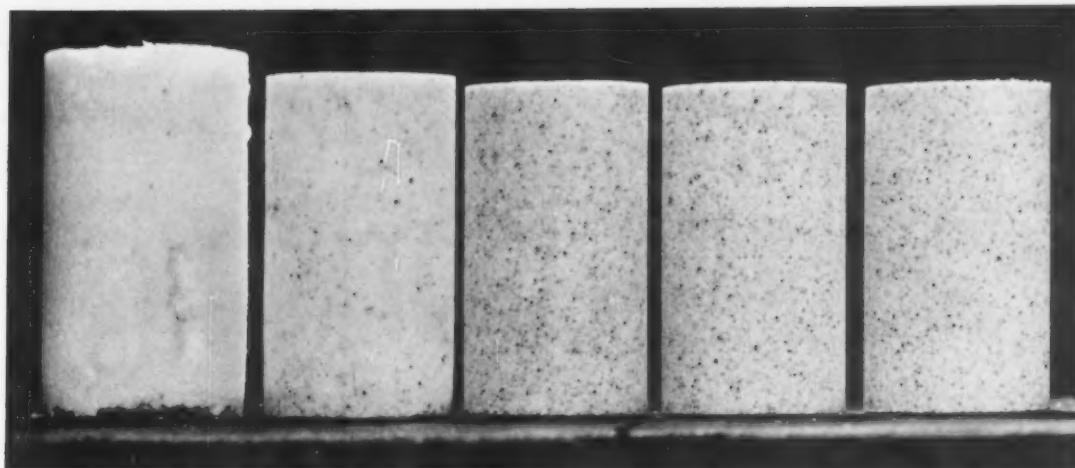


Fig. 9—Effect of alumina addition on expansion of silicate bonded sand at 1400 C (2552 F).

to beyond 300 C (572 F) strength after cooling falls to a minimum, which is reached when the heating temperature is about 500 C (932 F). As the heating temperature is raised beyond this, strength after cooling increases rapidly, as a result of fusing and later resolidification of the bond. This high strength increases the difficulty of removal of silicate-bonded cores.

Various organic materials are added to assist breakdown. These may be put into two classes:

1. Materials including coal dust, wood flour and peat, reduce the strength of the mold or core after gassing, as well as after heating. If the silicate is increased to give the same gassed strength as before the addition, the strength after heating returns almost to its original value. Coal dust may have a beneficial effect on penetration and surface finish, but from the point of view of obtaining better breakdown it would be simpler to reduce the silicate.
2. Materials which readily develop a bond when they lose a small amount of water. When these are included in the mixture the amount of silicate can be reduced and the gassed strength maintained. At high temperatures the organic binder is destroyed and strength on cooling reduced. These can be effective under some conditions. Sugars are widely used for this purpose.

Clays can have an important effect on breakdown because they completely change the pattern of the curve, showing the relation between temperature of heating and strength on subsequent cooling. The maximum at 300 C (572 F) is suppressed entirely, the minimum at 500 C (932 F) is reduced and takes place at a higher temperature, as does the subsequent increase. Using a normal 2:1 silicate, clay reduces gassed strength, but if the amount of silicate is raised in order to bring the gassed strength to the original figure, the changed pattern of strength after cooling persists. This is shown in Fig. 10.

In the absence of clay, cold strength after heating rose to a maximum after heating to 300 C (572 F), fell to a minimum after heating to 500 C (932 F) and

then rose rapidly. The addition of 2 per cent zeppiolite, a clay chosen because it has negligible dry strength, reduces gassed strength, but this is restored by raising the silicate addition to 6 per cent. The strength after cooling is below that of the clay-free sand over the whole range of heating temperatures except at temperatures above 1000 C (1832 F), when cooled strength begins to fall as a result of quartz crystobalite change.

The effect of using the waste foundry sand with a low ratio silicate is even more interesting. This is shown in Fig. 11, in which the upper curve shows the strength after cooling of a silica sand bonded with a normal silicate, and the lower curve that of waste foundry sand bonded with a low ratio silicate. By using the latter, residual strength is greatly reduced over the whole range and core removal made less difficult.

When, however, the casting is such that the core reaches a temperature of 800 C (1472 F), difficulty in removal is to be expected. With such castings, not only does the core reach a high temperature, but it remains at that temperature for a considerable time, during which fritting of grains surrounded by molten silicates continues, with an increase in residual strength.

### NEED FOR CONTROL

Castings have been made successfully using sand taken at random from a green sand system and with moisture contents as high as 10 per cent. This may give the impression that any sand from either the foundry floor or dump can be used, but this is not so. The sand must be free from foreign material, and the clay content must be such that after the addition of silicate the sand is not too tough for easy ramming.

In most cases, it will be found that a mixture of equal parts of dry used green sand and undried silica sand has a moisture content below 3 per cent and can be rammed without difficulty. It is advisable to make frequent tests for moisture content, and 3 per cent should not be exceeded if the molds have to stand for some time before pouring.

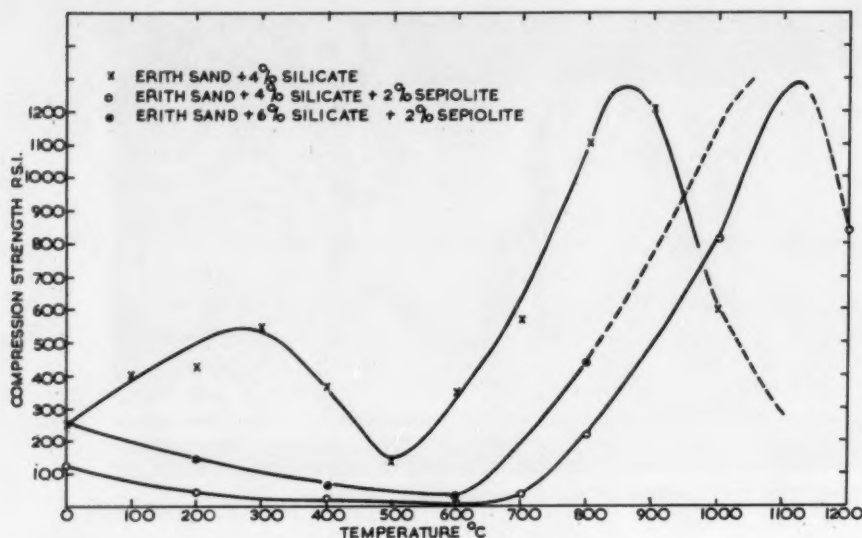


Fig. 10 — Effect of certain clays on strength after cooling of silicate bonded sand.

Satisfactory molds have been made using a silicate with 1.6:1 ratio to bond a mixture of equal parts of recovered sand previously bonded with silicate and a new silica sand. The moisture content of the mixed sand was one per cent, and this could be obtained by using the dry recovered sand with new sand of which only half had been dried. It was therefore necessary to dry only one quarter of the sand in the mold. Only normal gassing time was required and the problem of re-using sand was partly solved.

#### CONCLUSION

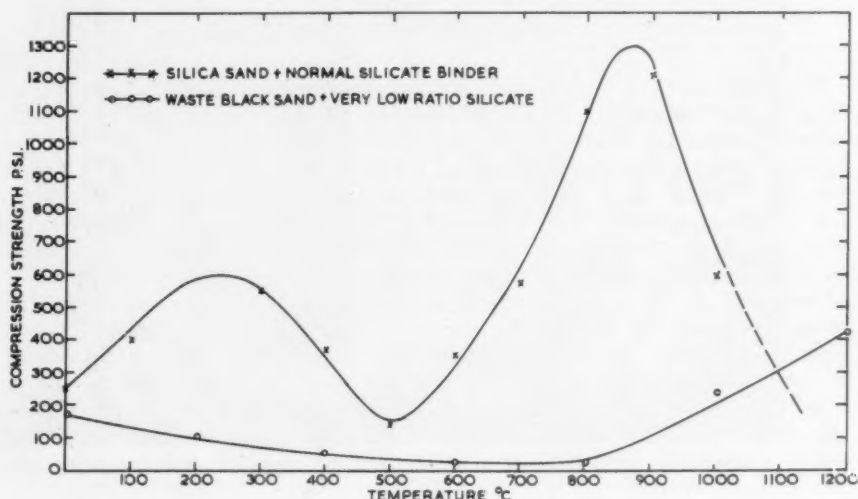
1. Sand containing appreciable quantities of clay and water can be used in the  $\text{CO}_2$  process provided that the sodium silicate has a silica/soda ratio of about 1.6:1.
2. The addition of sodium silicate to a clay-bonded sand increases toughness, and the upper limit of clay content must be such that ramming of the mold or core is not difficult.
3. Sand from a green sand system which has been heated until most of the bond has been destroyed is particularly suitable.

4. Molds with a high moisture content deteriorate rapidly after gassing and the final moisture content should not exceed 3 per cent.
5. The limits of toughness and moisture content are satisfied if the sand consists of equal parts of dry used sand from a green sand system and undried silica sand.
6. Clay reduces strength after cooling from high temperature and makes core removal less difficult.
7. Low ratio silicate can be used to rebond sands containing appreciable quantities of sand recovered after use in the  $\text{CO}_2$  process, provided that moisture content is raised.
8. The efficiency of the gassing procedure is increased if a mixture of equal parts of air and  $\text{CO}_2$  are used instead of  $\text{CO}_2$  alone. The advantage to be obtained from the mixed gases increases as the permeability of the mold falls.

#### ACKNOWLEDGMENT

The author wishes to express his thanks to the Council and Director of the British Cast Iron Rsch. Assoc. for permission to publish this paper.

Fig. 11 — Strength after cooling from high temperatures for silica sand bonded with normal silicate, and waste black sand bonded with low ratio silicate.



## Detroit's Giant Cobo Hall Provides Showcase for AFS '62 Exposition

A world-wide audience and the nation's outstanding exposition hall are added bonuses to the metalcasting industry's outstanding events in 1962—the AFS 66th Castings Congress & Exposition.

In addition, the 29th International Foundry Congress will be held in conjunction with the AFS-sponsored events. Outstanding foundrymen from all over the world will meet to exchange the latest technological advances.

This gives an international audience an unparalleled opportunity to hear and see the latest in foundry progress. Expositions are not included as a part of the International Foundry Congresses. The AFS Exposition will give

overseas visitors a chance to observe the latest in U. S. advances.

The International, last held 10 years ago in this country, will provide current international research and developments. Traditionally, U. S. foundrymen have adopted European techniques to mass production methods. Each of the 22 countries belonging to the International Association of Foundry Technical Associations, will submit at least one technical paper to the International Congress.

This program will be in addition to the 100 or more contributions sponsored by the AFS technical divisions at the Castings Congress. The combined program as-

ures that every phase of the metalcasting industry will be covered.

Selection of Cobo Hall, the nation's newest facilities for trade shows, was made on the basis of combining a central location with a show case in keeping with the caliber of the Exposition and technical sessions.

Detroit, the nation's automobile capital and one of the major manufacturing centers, has 75 per cent of the AFS membership within a 500-mile radius. Its location in the heart of the foundry industry is expected to stimulate a new attendance figure.

An all-time high response by exhibitors indicates their evaluation of Cobo Hall as

an exhibit center. On July 5, assignment day, a total of 106 exhibitors were assigned to prime locations in the huge hall.

Additional applications continue to be received at this unprecedented rate.

Signing of the AFS-sponsored ground rules for expositions has dispelled fears of spiraling exhibit costs. The rules and regulations outline provisions for all parties participating in expositions and is aimed at stimulating U. S. trade shows.

Cobo Hall, within walking distance of most of the major Detroit hotels and downtown motels, contains 300,000 square feet of air conditioned exhibit space. Among its many advantages are 30 foot ceilings, fluorescent lighting, convenient locations of all utilities, 32 meeting rooms, a banquet hall, a cafeteria, and a coffee shop. Detroit's major traffic artery passes directly under the hall.



Detroit's Cobo Hall, the nation's newest facilities for industrial trade shows, will be the site of the AFS 66th Castings Congress & Exposition. These will be held in conjunction with the 29th

International Foundry Congress. Detroit's downtown buildings are in the background with Cobo Hall in the foreground. The spiraling structure is the ramp for rooftop parking.

## 1962 AFS National Apprentice Contest Competition Opens on Oct. 1

Competition opens Oct. 1 in the 1962 AFS Robert E. Kennedy Memorial Apprentice Contest. Last year the national event drew 129 entries, the largest number to date. A total of 20 chapters took part in the program, also an all-time high.

The contest has been held annually since 1924 to stimulate the development of individual skills and craftsmanship in patternmaking and the foundry trades.

Competition is held in five categories, wood patternmaking, metal patternmaking, iron molding, steel molding, and non-ferrous molding. Any learner who has not more than five years patternmaking experience, nor more than four years molding experience is eligible. AFS membership is not required for the entrant or his company.

Cash prizes are awarded to the first three winners in each of the five divisions. First place winners receive \$100, 2nd place, \$75, and 3rd place, \$50. In addition, round trip travel expenses will be paid to and from Detroit, site of the 1962 Castings Congress & Exposition.

Where an AFS chapter holds a local elimination contest, any and all entries from plants located in the chapter's territory must clear through the local chapter contest. Only if successful in such local chapter contests will entries be accepted for national contest judging. In the

event no local chapter contest is held, entries may be submitted directly for national judging.

Where an individual plant conducts a local elimination contest for its own employees, only one entry will be accepted in each division. If three or more plants participate in a local elimination contest, as an inter-plant contest or local chapter contest, the best three entries may be entered in each of the five divisions.

All chapters and plants intending to hold local elimination contests must furnish promptly to the AFS Central Office, the name of one person as the official contact for all correspondence concerning the contest.

At the time patterns or blueprints are requested for local contests, the AFS Central Office must be furnished with the full names, companies, and respective divisions of all intended contestants. The official numbered identification tags for use by all contestants, can not be provided until such information is received, since all entry numbers in the national contest are identified only at the AFS Central Office.

Prior to actual receipt of entries for judging, all contest activities and correspondence must be addressed only to the AFS Education Director, Golf & Wolf Roads, Des Plaines, Ill.

## Albion Malleable Receives Million Dollar Shell Order

Albion Malleable Iron Co., Albion, Mich., has received a million dollar order to produce 173,000 rounds of 81 mm mortar shells. Special foundry processes and control methods were developed by Albion under contract to U. S. Army Ordnance. The high fragmentation cast pearlitic malleable shells replace steel forgings.

At a special ceremony held at Albion, Mich., Major General William K. Ghormley, Commanding General of the U. S. Army Ordnance Special Weapons-Ammunition Command, Dover, N. J., stated that "Albion has succeeded in achieving a scientific breakthrough."

Collins L. Carter, president, Albion Malleable Iron, said that the contract award "culminates a joint Army Ordnance-Albion effort that began in 1953."

## East Coast Regional Set for Sept. 21-22

New horizons in metalcasting will be stressed at the East Coast Regional to be held Sept. 22-23 at the Statler Hilton Hotel, New York. The conference is sponsored by the Metropolitan, Chesapeake, and Philadelphia Chapters. Sessions will be held for gray and ductile iron, brass and bronze, aluminum and magnesium, malleable, and steel.

The tentative speakers:

### Gray and Ductile Iron

"Education and Management Improvements in the Foundry," H. F. Taylor, Massachusetts Institute of Technology, Cambridge, Mass.; "Engineering Properties of the Various Cast Irons," V. H. Patterson, Vanadium Corp. of America, Chicago; "Influence of Inoculation on the Structure of Gray Cast Iron at Various Equivalences," H. D. Merchant, Owens Illinois Technical Center, Toledo, Ohio; "Post Inoculation of Ductile Iron," W. C. Jeffrey, McWane Cast Iron Pipe Co.,



Major General W. K. Ghormley, Commanding General of the U. S. Army's Ordnance Special Weapons Ammunition Command is greeted by General N. O. Moore. In center is Albion Malleable Iron Co. president Collins L. Carter. Albion Malleable received a million dollar order to produce cast pearlitic mortar shells. (U. S. Army Photo).

Birmingham, Ala.; "Progress of Solidification in Inoculated and Uninoculated Gray Iron," H. D. Merchant.

Also, "The Use of Calcium Carbide in Acid Cupolas," R. A. Clark, Union Carbide Metals Co., Cleveland; Harold Ruf, Grede Foundries, Inc., Milwaukee and E. A. Welander, John Deere & Co., East Moline, Ill., "Shop Course on Ductile Iron Production."

#### Brass and Bronze

"The Use of Wetting Agents in the Brass and Bronze Foundries," W. N. Richards, Deynor Corp., Mamaroneck, N. Y.; "Round Grain Carbon Sand—A New Molding Medium for Brass and Bronze," E. G. Gentry, Humble Oil & Refining Co., Detroit; "Superston, A New High-Strength Aluminum Bronze," Frank Herlihy, American Brake Shoe Co., Mahwah, N. J.; "New Developments in Melting Brass and Bronze," H. F. Gauker, Ajax Magnethermic Corp., Trenton, N. J.; "AFS Brass and Bronze Research at the University of Michigan," R. W. Ruddle, Fosco, Inc., Cleveland.

#### Aluminum and Magnesium

"Latest Developments in Core Binders for Aluminum Sand and Permanent Mold Castings," R. M. Ovestrud, Reichhold Chemicals, Inc., Elizabeth, N. J.; "Present Day Melting Equipment for Non-Ferrous Metals," R. P. Dunn, Lindberg Engineering Co., Chicago; "Degassing Aluminum with Nitrogen-Chlorine Mixtures," representative from National Cylinder Gas Co., North Bergen, N. J. Additional talks will be held on the newest magnesium casting alloys and aluminum permanent mold practice.

#### Malleable Iron

"Pearlitic Malleable Iron and Its Applications," Prof. Richard

Schneidwind, University of Michigan; "Laboratory Controls in a Malleable Shop," Gordon Mannweiler, Eastern Co., Naugatuck, Conn.; "Chemical Controls in the Manufacture of Duplex Malleable," W. R. Jaeschke, Whiting Corp., Harvey, Ill.; "Recent Developments in Malleable Iron," Norman Birch, Albion Malleable Iron Co., Albion, Mich.

#### Steel

Talks will be held on "AFS Research Investigating the Formation of Macro-Inclusions in Steel Castings," "Metal Reactions of Concern to the Furnace Operator," "Vacuum Melting Techniques," "Press Forging of High-Alloy Steel Castings," "Developments of High-Strength Steel Castings," "Microradiography of Steel Castings," and "Important Developments in the European Steel Foundry Industry."

## Missouri Regional on Sept. 21-22

A combination of new technology and re-emphasis of fundamentals will be presented Sept. 21-22 at the Missouri Valley Regional Foundry Conference. Sponsors are the University of Missouri School of Mines and Metallurgy and the AFS St. Louis, Mo-Kan, Tri-State and Missouri School of Mines Student Chapters.

Steel, iron, and non-ferrous sessions will be conducted. In addition, an educational shop course and non-destructive testing demonstration will be presented. Robert C. Kane, Midvale Mining & Mfg. Co., St. Louis, is the general conference chairman.

On Thursday, Sept. 21, registra-



Students at T&RI course in sand testing held in Detroit, shown taking course test. Instructors at the head table are Ray Daksiewicz, Harry W. Dietert Co.; Frank Csizmadia, Kelsey-Hayes Co.; H. W. Dietert, Harry W. Dietert Co.; AFS Education Director R. E. Betterley; and Randolph Dietert and A. L. Graham, Harry W. Dietert Co.

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Circle No. 158, Pages 141-142

tion will start at 8:30 in the lobby of the Student Union Building. At 9:45, John A. Rassenfoss, American Steel Foundries, will present "New Development in Foundry Practices." A luncheon will be held on campus.

The afternoon sessions include: Steel—"Desulphurization of Steel," Butch Gray, Air Reduction Co.; "Refractories for the Foundry Industry," Russell Pardee, Kaiser Aluminum & Chemical Co.

Iron—"Ductile Iron," Jeff Green, Sorbo-Mat Process Engineers; "Marketing of Engineering Irons in the Midwest and Southwest," Howard Randall, International Nickel Co.

Non-Ferrous—"High Quality Aluminum Castings," Alan B. De-Ross, Kaiser Aluminum & Chemical Co.; "A-B-C's of Molding Sand Practices," Clyde A. Sanders, American Colloid Co.

Sessions on Friday morning are: Steel—"New Developments in Core and Moldmaking for the Steel Foundry," Victor M. Rowell, Archer-Daniels-Midland Co.; "Sand for Molding and Coremaking," Thomas W. Seaton, American Silica Sand Co.

Iron—"New Core and Mold Proc-

esses for the Iron Foundry," Anton Dorfmueller, Jr., Archer-Daniels-Midland Co.; "Gating and Riserling," H. Otey Merriwether, Jr., Lynchburg Foundry Co.

Non-Ferrous—"Control of Quality in the Brass Foundry," Fred L. Riddell, H. Kramer & Co.; "New Developments in Core Practices," Robert Jacoby, St. Louis Coke & Foundry Co.

The afternoon will see an Educational shop course and demonstration, non-destructive testing, by Associate Professor Robert V. Wolf, Dept. of Metallurgical Engineering, School of Mines and Metallurgy.

### Five Courses Remaining In 1961 T&RI Schedule

Five courses remain in the 1961 schedule for the AFS Training & Research Institute courses. One will be held in September, two in October, and one each in November and December.

These include:

*Course No. 11—Scrap—Causes and Remedies, Sept. 13-15, Chicago, Fee, \$60.* A critical analysis of

scrapped castings, types of imperfections, causes and corrective measures. Specific problems are welcomed for discussion.

*Course No. 12—Metallurgy of Gray Iron, Oct. 2-4, Chicago, Fee \$60.* Covers metallurgy of gray iron as applied to foundry production and castings application. Recommended for metallurgists, engineers, foremen, supervisors, and management.

*Course No. 13—Sand Control and Technology, Oct. 16-18, Detroit, Fee \$60.* Covers mold wall movement, hot deformation, creep deformation, mold atmosphere, heat transfer, mechanical properties, and metal penetration.

*Course No. 14—Cleaning Room Operation, Nov. 1-3, Chicago, Fee \$60.* Emphasis placed on how cost-reduction steps can be implemented into specific foundry operations.

*Course No. 15—Production Scheduling and Control, Dec. 4-6, Chicago, Fee, \$60.* Basic understanding and application of production criteria for effective and economical utilization of equipment, materials, and manpower in the production of ferrous and non-ferrous castings.

## NEW! Stahl Self-Pouring AUTOCAST

With Standard Dual Power Unit, the Permanent Mold Casting Machine That:

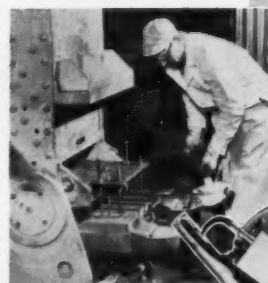
- Pours "two-up" with one man.
- Eliminates turbulence with simple gating.
- Pours exactly alike at a given setting.
- Adjusts for any rate of pour.
- Prevents flash at bottom of mold.
- Assures progressive solidification.

Write for literature describing other standardized permanent mold operating equipment.

### STAHL SPECIALTY COMPANY

KINGSVILLE, MISSOURI

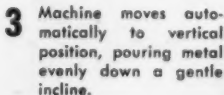
Better Castings from Better Equipment



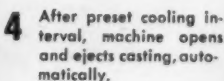
2 Operator pours into holding basins.



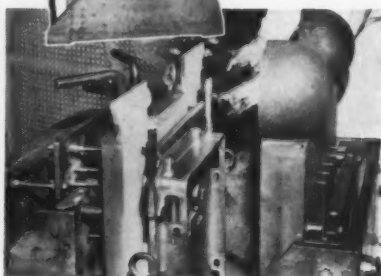
1 Operator pushes button on control panel to start cycle.



3 Machine moves automatically to vertical position, pouring metal evenly down a gentle incline.



4 After preset cooling interval, machine opens and ejects casting automatically.



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## 1961-1962 Regionals

### Missouri Valley Regional Sept. 21-22

Missouri School of Mines, Rolla, Mo.

### East Coast Regional Sept. 22-23

Statler Hilton Hotel, New York

### Ohio Regional Oct. 5-6

Netherland Hilton Hotel, Cincinnati

### New England Regional Oct. 13-14

M.I.T., Cambridge, Mass.

### Michigan Regional Oct. 19-20

Michigan State University, East Lansing, Mich.

### Purdue Regional Oct. 26-27

Purdue University, Lafayette, Ind.

### Wisconsin Regional Feb. 8-9

Hotel Schroeder, Milwaukee

### Southeastern Regional Feb. 15-16

Thomas Jefferson Hotel, Birmingham, Ala.

### Texas Regional March 15-16

Menger Hotel, San Antonio, Texas

## Wisconsin Renames Department

Wisconsin University's College of Engineering has changed the name of its department of mining and metallurgical engineering to Department of Minerals and Metals Engineering.

Prof. Philip C. Rosenthal, department chairman, explained that the department's new name better fits its new curriculum which has been put into effect largely during the past year.

## Elect Zinc Officers

F. R. Jeffery, National Zinc Co., New York, has been elected as president of the American Zinc Institute. Three new vice-presidents were named: J. J. Lennon, American Metal Climax, Inc., New York; C. E. Schwab, Bunker Hill Co., Kellogg, Idaho; and H. L. Young, American Zinc Sales Co., St. Louis. Re-elected were G. H. LeFevre, U. S. Smelting, Refining & Mining Co., New York, as treasurer, and J. L. Kimberley as executive vice-president and secretary.

Directors elected to terms expiring in 1964 were: H. D. Carus, Mattiessen & Hegeler Zinc Co., La Salle, Ill.; Francis Cameron, St. Joseph Lead Co., New York; C. O. Dale, Eagle-Picher Co., Miami, Okla.; R. G. Kenly, New Jersey Zinc Co., New York; E. H. Klein, New Jersey Zinc Co., New York; J. J. Lennon, American Metal Cli-

max, Inc., New York; R. F. Orr, Athletic Mining & Smelting Co., Ft. Smith, Ark.; C. G. Rice, U. S. Smelting, Refining & Mining Co., Boston; C. N. Waterman, American Smelting & Refining Co., New York; and H. L. Young, American Zinc Sales Co., St. Louis.

## Executive Predicts Increasing Production of Cast Iron Pipe

Bright prospects for increased production of cast iron pipe are seen by John Madden, president and chairman of the board, James B. Clow & Sons, Inc. Madden, speaking at a board meeting in Birmingham, Ala., predicted higher production in the last quarter of 1961 and continuing into 1962. The forecast was made despite the fact that the cast iron pipe business has been off for more than a year, particularly in the South and Southeast.

## Wheland Co. Merges

Wheland Co., Chattanooga, Tenn., has been merged into Gordon Street, Inc., the company that has owned a substantial majority of stock for a year. The Wheland name will no

longer be used. The Broad St. operation is now Wheland Foundry, Division of Gordon Street, Inc., and the plant on Signal Mountain Road is now Wheland Products, Division of Gordon Street, Inc.

## Belgium Establishes Foundry Technical Center

A Belgium foundry center, Centre Belge De Fonderie, has been established in Brussels. It will coordinate, direct, and develop all collective, scientific, technical, technological, and technico-economical activities in the Belgian foundry industry.

It will also assist foundries with technical assistance, development of professional training, promotion of castings, and diffusion of Belgian and foreign technical documentation.

J. Goffart, head of the Seraing foundries of Cockerill-Ougree is president of the Center. F. Hebrant, manager of the Research Center of the Belgian Metallic Industries is manager. A. Pirson is secretary of the Center as well as secretary of the Association Technique de Belgique.

# GRAPHITE FLUXING TUBES ?

You will find none finer than the fluxing tubes

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We invite you to compare our reliability of service and promptness of delivery.



## GREAT LAKES CARBON CORPORATION

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Circle No. 100, Pages 141-142

## Special Metals Plans Production Increase

Special Metals, Inc., New Hartford, N. Y., which recently purchased the metals division of Kelsey-Hayes Co. for \$7.7 million, is planning increases in its production facilities and research. It is continuing its present line of vacuum melted alloys.

The firm has an annual capacity of seven million pounds. A 5000-lb furnace, constructed at a cost of more than \$1 million, is the largest vacuum induction furnace in the U. S. The company is active in developing high strength steels for rocket casings, landing gear applications, and the cryogenic field.

## Wellman Beats Safety Average

Wellman Bronze & Aluminum Co., Bay City, Mich., has completed more than two million consecutive man-hours of work without a loss-time injury for its over 500 employees.

The two million man-hour work mark for the aluminum and magnesium foundry dates back to July 20, 1958. Between 1956 and the pres-

ent, Wellman employees have averaged 1.5 loss-time injuries per million man-hours, while U. S. Dept. of Labor Statistics show the non-ferrous average for this period to be 19.2 injuries.

## Will Conduct Core School

A 2½ day course on a new mold control method will be conducted without charge by the Harry W. Dietert Co., Detroit. Actual sand preparation work and molding will be performed. Classes of 25 will be held the first part of each week during October, November, and December.

## Seek Data on Ductile Alloys

Information on the effects of alloys, both beneficial and detrimental, on the properties of ductile iron is being compiled by the Ductile Iron Division Alloying Committee. Those having information are requested to forward it to the committee chairman D. L. Crews, James B. Clow & Sons, Inc., Coshocton, Ohio, or to L. S. Wilcoxson, International Nickel Co., New York 5.

## New Technique for Magnesium Injection

A new method of injecting pure magnesium into gray iron and white cast iron has been developed by Jamestown Malleable Iron Div., Blackstone Corp., Jamestown, N. Y. The process has application in acid cupola melted gray and ductile iron as well as malleable iron.

The injection of pure magnesium reportedly allows freedom to choose a variety of combinations of chemical elements. In malleable iron, when carbon levels of 2.20-2.40 per cent are desired, silicon may be raised without fear of mottling and section size is not limited. The increase in silicon makes possible a fast, complete anneal, producing "Grade A" quality malleable, meeting A.S.T.M. requirements. This results in complete elimination of combined carbon and primary graphite. Sensitivity to critical cooling temperatures is lessened and short cycle annealing becomes possible.

## International Minerals Buys Aristo Corp. of Detroit

International Minerals & Chemical Corp., Skokie, Ill., has acquired Aristo Corp., Detroit, manufacturer of binding materials for foundry cores. International Minerals exchanged common stock for all the stock of Aristo, a 33-year old family-owned corporation. Aristo will be operated as a wholly-owned subsidiary. Present management and personnel will be retained.

## J. S. Morie Acquires Goff

Jessie S. Morie & Son, Inc., Mauricetown, N. J., has acquired Daniel Goff Co., Inc., which is now operated as the Goff Div. Changes in the sales department include R. Joseph Fitzgerald as sales manager of the combined companies; Edward C. Klank, sales representative in eastern Pennsylvania; and Ronnie Johnson, New Jersey sales representative.

## Airco Buys Speer Carbon

Air Reduction Co., New York, has signed the formal agreement covering the acquisition of Speer Carbon Co., St. Mary's, Pa. The business will continue to be operated by Speer Carbon's management from St. Mary's.

## there's an AIRETOOL Pneumatic Grinder for every job ...

### ROUGH GRINDING ...

Models 600 and 700, vertical and horizontal, with speeds up to 8000 r.p.m., handle general grinding, wire wheel work, snagging and buffing, fast and efficiently. Easy operation. Muffled motors available.



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Model 500-V for fast, vibration-free, feather-edge sanding and fine metal finishing. Speeds up to 4000 r.p.m.



### INTRICATE DIE GRINDING ...

Models 200-G and 300-G for precision grinding, filing and cutting at vibrationless speeds of 60,000 and 38,000 r.p.m. Available with muffled motors. Models 400-G and 500-H for large die work.

When you want production and precision ... you need Airetool. Write for Bulletin 70.



Representatives in principal cities of the free world

Circle No. 161, Pages 141-142

# AFS CHAPTER NEWS

## AFS Admits 15th Student Chapter



Participating in the installation of the General Motors Institute AFS Student Chapter. Shown are: AFS Secretary A. B. Sinnett; Co-Presidents William Graff and Joe Bostater; AFS National Director C. J. Lonnee; Dr. Harold Rodes, president, General Motors Institute; Harold G. Warner, vice-president, GMC and general manager, Cadillac Motor Car Div.; and AFS Regional Vice-President T. T. Lloyd.

General Motors Institute Student Chapter has become the 15th AFS Student Chapter and the second to join the Society this year. Ryerson Institute of Technology, Toronto, Canada, was admitted earlier this year.

Installation ceremonies held Aug. 1 at Flint, Mich., were attended by AFS representatives and General Motors personnel. AFS Secretary A. B. Sinnett presented the chapter charter to Dr. Harold P. Rodes, president, General Motors Institute. The chapter also received the cast iron rattle given traditionally to the newest chapter.

General Motors Institute students are under a co-operative engineering program, dividing their time between schooling and work in the various General Motors plants. Consequently, two sets of officers were elected. Officers for 1960-61 are: Presidents, Joe Bostater and William Graff; Vice-Presidents, Joe Peganoff and James Corbett; Secretaries, William Lutz and John Tobiczky.

Officers for 1961-62 are: Presidents, Marvin Galbalski and Ray Landskroner; Vice-Presidents, Tom Weigandt and Bob Roach; Secretaries, Tom Keenan and Mike Pike. Faculty advisors to the group are John Lowe and Don Bergh. Chairman of the Industrial Advisory Committee is John Ikner of Chevrolet Grey Iron.

Other AFS representatives were AFS Regional Vice-President T. T.

Lloyd, Albion Malleable Iron Co., Albion, Mich., who presented a check for chapter operational funds; AFS National Director C. J. Lonnee, Alloyed Grairon Castings Corp., Ravenna, Mich., who is the AFS National Director for the chapter; Detroit Chapter Chairman R. H. Sutter, Sutter Products Co., Holly, Mich.; and Central Michigan Vice-Chairman K. W. Rhoads, Engineering Castings Co., Marshall, Mich.

A list of the 15 student chapters belonging to the American Foundrymen's Society and their advisors will be found on the following page.



OREGON—Jack Stephenson, Dependable Shell Core Machine Co., right, presented golfing trophies to winners. Guest low gross was won by Bob Butler, Oregon Brass Foundry, and low member guest trophy was won by Hal Story, also of Oregon Brass. Blackboard was supplied by Dependable Pattern Works—by Bill Walkins.

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MISCHMETAL

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### • controls

subversive elements in  
Ductile Iron

### • improves

pressure tightness and high temperature creep resistance of  
magnesium alloy castings

### • enhances

castability in precision casting of  
superalloys and stainless steels

### • increases

oxidation resistance of nickel-chromium alloys, ductility and impact properties of cast steels, and hot workability of stainless steels

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RONSON METALS CORPORATION

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and Alloys since 1915.

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## Student Chapters Form Important Part of AFS

Fourteen Student Chapters of the American Foundrymen's Society play an important role in the AFS program. Student Chapters work closely with various AFS Chapters and local foundrymen. Stimulation of students is considered an important part of the over-all Society planning.

The Student Chapters and their faculty advisors are:

University of Alabama—Prof. Harry D. Bradshaw.  
Brooklyn Polytechnic Institute—Dr. William H. Ruten.  
General Motors Institute—John Lowe and Don Bergh.  
University of Illinois—Prof. James L. Leach.  
Massachusetts Institute of Technology—Prof. Howard F. Taylor.  
Michigan State University—Prof. H. L. Womochel.  
University of Michigan—Dr. R. A. Flinn.

Missouri School of Mines—Prof. Robert V. Wolf.  
Ohio State University—Dr. D. C. Williams.  
Oregon State College—Prof. Lloyd M. Frazier.  
Pennsylvania State University—Prof. A. B. Draper and Prof. W. P. Winter.  
Ryerson Institute, Toronto, Ont.—Harold Howard.  
Texas A & M College—Prof. Edward D. Kranz and Prof. Stewart E. Brown.  
University of Wisconsin—Prof. Richard W. Heine.  
Wentworth Institute—Prof. J. Gerin Sylvia.



WENTWORTH INSTITUTE—Dennis J. Moore, center, recipient of F.E.F. \$350 award, shown with Institute President Beatty, right, and J. G. Sylvia, senior instructor in charge of foundry department.



PHILADELPHIA—New officers are (left) Vice-Chairman Philip J. Keeley, Northern Bronze Corp., Philadelphia, and Chairman Karl Kostenbader, Bethlehem Steel Corp., Bethlehem, Pa.—by Leo Houser and E. C. Klank



# Hausfeld

*stationary crucible furnaces*

### FOR BRASS OR BRONZE MELTING

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**CAMPBELL-HAUSFELD METAL MELTING FURNACES**

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## "One Stop" Service for Metalcasters

On this page you will find an alphabetical reference guide to products, processes, and services offered by advertisers of MODERN CASTINGS. In the same column you will see the names of the advertisers offering the service and the page number of the ads.

This is designed as a "one stop" reference for busy metalcasters in search of important information. Each advertiser has prepared this important material with you in mind. Keeping well-informed is essential in today's highly competitive market.

Another important step to increase your "one stop" reading is the merging of "New Products and Processes" and "For the Asking" into a single, easy-to-read section entitled "Metalcasting Products and Processes."

Use the handy Reader Service Card below to build a valuable reference file of new products, processes, and techniques. The manufacturers who participate in this section are eager to send data to any qualified reader of MODERN CASTINGS.

SEPTEMBER 1961—1

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## Future Meetings and Exhibits

Aug. 28-Sept. 1 . . American Society of Mechanical Engineers, International Heat Transfer Conference, University of Colorado Campus, Boulder, Colorado.

Sept. 17-21 . . Non-Ferrous Founders' Society, Annual Meeting, Shawnee Inn, Shawnee on Delaware, Pa.

Sept. 18-20 . . Non-Ferrous Founders' Society, Annual Meeting, Shawnee Inn, Shawnee-on-Delaware, Pa.

Sept. 21 . . Cast Bronze Bearing Institute, Annual Meeting, Shawnee Inn, Shawnee-on-Delaware, Pa.

Sept. 21-22 . . Missouri Valley Regional Conference, Rolla School of Mines, Rolla, Missouri.

Sept. 22-23 . . East Coast Regional Foundry Conference, Statler-Hilton Hotel, New York.

Sept. 24-26 . . Steel Founders' Society of America, Fall Meeting, The Homestead, Hot Springs, Va.

Sept. 25-26 . . Steel Founders' Society, Fall Meeting, The Homestead, Hot Springs, Va.

Oct. 5-6 . . Ohio Regional Conference, Netherland Hilton Hotel, Cincinnati.

Oct. 13-14 . . New England Foundry Conference, Massachusetts Institute of Technology, Cambridge, Mass.

Oct. 16-18 . . The Magnesium Association, Annual Convention, Belmont Plaza Hotel, New York.

Oct. 16-21 . . National Industrial Sand Association, Semi-Annual Meeting, The Greenbrier, White Sulphur Springs, W. Va.

Oct. 19-20 . . Michigan Regional Foundry Conference, Michigan State University, East Lansing, Mich.

Oct. 19-21 . . Foundry Equipment Manufacturers Assn., Annual Meeting, The Greenbrier, White Sulphur Springs, W. Va.

Oct. 23-27 . . American Society for Metals, Detroit Metal Show (43rd National Metal Congress and Exposition), Cobo Hall, Detroit, Mich.

Oct. 26-27 . . Purdue Metals Castings Conference, Purdue University, Lafayette, Ind.

Oct. 26-27 . . 2nd Biennial North Central States Apprenticeship Conference, Conrad Hilton Hotel, Chicago.

Nov. 13-15 . . Steel Founders' Society of America, Technical & Operating Conference, Pick Carter Hotel, Cleveland.

Nov. 15-17 . . National Foundry Association, Annual Meeting, Savoy-Hilton Hotel, New York.

May 7-11, 1962 . . AFS 66th Annual Castings Congress and Exposition, In conjunction with The 29th International Foundry Congress . . Cobo Hall . . Detroit.

## AFS Chapter Meetings

SEPTEMBER 10-OCTOBER 10

Canton District . . Sept. 28 . . Brookside Country Club, Barberton, Ohio . . A. D. Barczak, Superior Foundry Co., "Quality Control."

Central Illinois . . Oct. 2 . . Vonachen's Junction, Peoria, Ill.

Central Indiana . . Oct. 2 . . Athenaeum Club, Indianapolis . . J. A. Terpenning, Archer-Daniels-Midland Co., "Furan Binders."

Central Michigan . . Sept. 20 . . Hart Hotel, Battle Creek, Mich. . . Herbert J. Weber, AFS, "Heat Control In The Foundry."

Central Ohio . . Sept. 11 . . Maennechor Club, Columbus, Ohio . . Larson Wile, Lynchburg Foundry, "Core Practice With Emphasis on Shell Cores" . . Oct. 9 . . Maennechor Club, Columbus, Ohio, C. A. Sanders, American Colloid Co., "Good And Bad Molding Sand Practice In All Metals."

Cincinnati District . . Sept. 11 . . Wigwam Restaurant, Cincinnati, Jack Giddens, Foseco, Inc., "Exothermics."

Corn Belt . . Sept. 15 . . Cowles Lake, Omaha, Nebr., *Get Acquainted Night.*

Metropolitan . . Oct. 2 . . Military Park Hotel, Newark, N. J., J. H. Schaum, Modern Castings, "What's New in Metal Castings."

Michiana . . Oct. 9 . . Fehlberg's, St. Joseph, Mich. . . R. P. Schauss, Werner G. Smith Co., "Causes and Corrections of Core Defects."

Northern Illinois & Southern Wisconsin . . Sept. 12 . . Morse Hills Golf Club, Beloit, Wis. . . Dr. O. A. Sander, Marquette University, "Control of Occupational Diseases In Foundries."

Northwestern Pennsylvania . . Sept. 25 . . Amity Inn, Erie, Pa., William W. Maloney, General Manager, AFS.

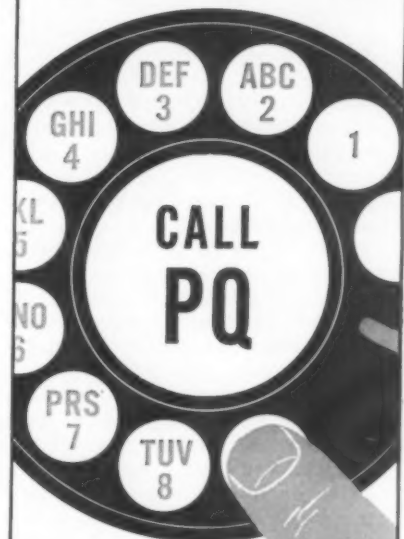
Ontario . . Sept. 22 . . Royal Connaught Hotel, Hamilton, Ontario . . J. E. Wilson, Canada Iron Foundries, Ltd. "Economic and Technical Considerations in the Carbon Injection Process."

St. Louis District . . Sept. 14 . . Edmonds Restaurant, St. Louis . . J. B. Caine, Hill & Griffith Co., "Slag, Snotters and Sand."

Toledo . . Oct. 4 . . Globe Motel, Toledo, Ohio . . S. C. Massari, Technical Director, AFS, "AFS and Your Future."

Twin City . . Sept. 12 . . Jax Cafe, Minneapolis . . Wayne Buell, Aristo Corp., "Furfural Cores."

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Prompt complete service is assured you from PQ's

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September 1961 143

## Metalcasters in the News . . .

**Fred E. Kasch** . . . is now assistant director of Gray Iron Research Institute, Inc., Columbus, Ohio. He will be responsible for introducing improved plant practices. Kasch was formerly foundry engineer for G.I.R.I.

**Ronald F. Altobelli** . . . has joined Planet Corp., Lansing, Mich., as sales engineer for automated foundry materials handling equipment.

**George R. Eusner** . . . elected executive vice-president of Davis Fire Brick Co., and associated companies at Oak Hill, Ohio. He was formerly chief of Refractory & Mineral Technology Div., United States Steel Corp., Monroeville, Pa.

**Anton Dorfmueller, Jr.** . . . division manager, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland, has been named also as manager for the east central and middle Atlantic states for A-D-M Chemical Group. Robert C. Fulton,

Minneapolis, has been named as manager for the Chemical Group's midwest region. Early this year he was assigned special duties within the Chemical Group.

**Eugene R. Crandall** . . . appointed manager H. K. Porter Co., Mullite Operations, Shelton, Conn. works.

**Charles R. Hauth** . . . named assistant manager, technical sales, Harbison-Walker Refractories Co., Pittsburgh, Pa.

**Charles D. Schmidt** . . . named manager, Detroit district sales office, Whiting Corp., Harvey, Ill.

**C. S. Anderson** . . . named chairman, board of directors, Belle City Malleable Iron Co., Racine Steel Castings Co., Racine, Wis. Other officers are: **B. H. Regenburg**, president and general manager; **K. M. Halvorson**, vice-president in charge of manufacturing; **W. R. Young**, vice-president in charge of industrial relations; **H. C. Cunningham**,

secretary and controller; **R. D. Leutner**, treasurer and assistant secretary; **E. K. Simonsen**, sales manager. Regenburg and Halvorson are also directors of the firm. C. S. Anderson has retired as chief executive officer and **R. J. Swartout** has retired as president and director.

**L. A. Kristoff** . . . is now executive assistant, Alloys & Chemicals Corp., Cleveland. In addition to executive duties will head the newly formed Special Products Div.

**Alexander H. Reynolds, Jr.** . . . presently treasurer, Leeds & Northrup Co., Philadelphia, is now a vice-president and will be responsible for long range planning. **Stephen Loidl, Jr.**, presently controller and manager of the accounting division, is now treasurer and controller.

**Malcolm Martin** . . . appointed superintendent, Coke & Chemicals Dept., Alan Wood Steel Co., Conshohocken, Pa.

**John V. Haider** . . . named manager, Pittsburgh sales office, Pangborn Corp., Hagerstown, Md. Pre-

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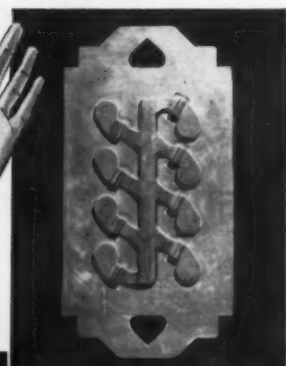
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Circle No. 165, Pages 141-142

### SCIENTIFIC PRESSURE CAST MATCHPLATES

CHECKED FOR QUALITY  
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Inspected at 7 points of manufacture for highest possible matchplate quality . . . Scientific is the only producer using patented new Fortschneider Shift Indicator.



**THE SCIENTIFIC CAST PRODUCTS CORP.**

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Circle No. 166, Pages 141-142

viously sales manager, he succeeds **John D. Wise** who retired after 14 years as Pittsburgh district manager. **Melvin R. Price** has joined Pangborn as sales engineer, Pittsburgh district.

**Dr. D. M. Gillies** . . . named as director of research for Union Carbide Metals Co., Div. Union Carbide Corp. He will be located in Niagara Falls, N. Y., succeeding **Dr. F. J. Shortsleeve** who has been appointed product manager of the company. Gillies was formerly assistant director of research, Linde Co., Speedway, Ind.

**Norman A. Matthews** . . . appointed group leader, ferrous metallurgy, of the Research Laboratory of International Nickel Co., Bayonne, N. J. He was previously with Metallurgical Products Dept., General Electric Co., Detroit.

**Michael Keimel** . . . is a sales representative for the Equipment Div., Milwaukee Chaplet & Supply Corp., Milwaukee.

**Ralph L. Lindner** . . . appointed to vice-president, general manager, Cleveland Div., Precision Castings Co., Cleveland. Plants are operated at Cleveland and Fayetteville, N. Y.

**Harley F. Gauker** . . . has been promoted to assistant division manager, Trenton Div., Ajax Magnethermic Corp., Youngstown, Ohio.

**James R. Coley** promoted to sales manager, Trenton Div.

**E. R. Bellows** . . . appointed manager of eastern casting sales, Foundry & Mill Machinery Group, Blaw-Knox Co., Pittsburgh, Pa.

**Alfred F. Bauer** . . . appointed manager, Doehler-Jarvis Div., National Lead Co. He has directed Doehler-Jarvis Div. research and development.

**Gordon C. Campbell** . . . promoted to chief industrial engineer, Alan Wood Steel Co., Conshohocken, Pa. Previously he was assistant chief industrial engineer.

**Raymond W. Cummings** . . . elected as vice-president of financing for Crouse-Hinds Co., Syracuse, N. Y. He continues to hold the positions as controller and secretary.

**Curry E. Ford** . . . named director of development for National Car-

bon Co., Div. Union Carbide Corp. He succeeds **Carl A. Odening**, appointed administrative assistant in the office of the president.

**Lyn Roberts** . . . appointed sales manager and **Don Paterson** sales representative of Combined Supply & Equipment Co. **Everett LeViness**, vice-president and sales manager has retired.

**James R. Higgins** . . . named purchasing manager—metals for Olin Mathieson Chemical Corp.

**Henry T. Swigert** . . . appointed vice-president, finance, Esco Corp., Portland, Ore. For the past two years he has been an Esco sales representative in Phoenix, Ariz.

**Earl Jackson** . . . for many years office manager of Milwaukee Chaplet & Supply Corp., Milwaukee, has been promoted to sales representative in the Supply Div.

**John R. Strom** . . . technical director of Roto-Finish Co., Kalamazoo, Mich., and Ransohoff Co., Hamilton, Ohio, has been promoted to vice-president. **Richard D. Taylor** has been named as marketing manager.

**M. L. Waton** . . . appointed mid-western district manager for Planet Corp., Lansing, Mich. He will make his headquarters in Chicago.

**Charles W. Brunstetter** . . . appointed general manager of Ispen Industries. He has been responsible for the development of the Refractories Metals Div. of Ispen Industries and served as manager of the division.

**Thomas M. Colligan** . . . has joined the sales department of H. P. Deuschler Co., Hamilton, Ohio. He will serve as sales representative in that area for ductile and gray iron castings.

**George C. Davis, Jr.** . . . appointed to a new position as director of technical planning for Kaiser Refractories & Chemicals Div., Kaiser Aluminum & Chemical Corp. He will be engaged in long-range planning aspects and continue to assume over-all direction of the technical service function. **Russell E. Pardee** has been appointed manager of technical services with headquarters at Oakland, Calif.

**William C. McCosh** . . . named director of marketing for National Carbon Co., Div. Union Carbide

Corp. He succeeds **Curry E. Ford**, recently appointed director of development for the company.

**Lewis I. Day** . . . secretary and treasurer, Buckeye Steel Castings Co., Columbus, Ohio, has been elected president of the Columbus Control of the Controllers Institute of America.

## Honors

**James H. Lansing** . . . executive secretary, Ductile Iron Society, Cleveland, and **Thomas E. Eagan**, chief research metallurgist, Cooper-Bessemer Corp., Grove City, Pa., have received awards of merit from the American Society for Testing Materials.

**Dr. Russell P. Heuer** . . . vice-president, General Refractories Co., Philadelphia, will receive the Francis J. Clamer medal of the Franklin Institute in October. The award is given for meritorious invention, discovery of research achievement in the field of metallurgy.

## Deaths

**Harold R. Saurer** . . . 61, chief metallurgist, Dayton Malleable Iron Co., Dayton, Ohio. He started in the foundry in 1924 after graduation from the University of Cincinnati and has served as chief corporate metallurgist since 1943.

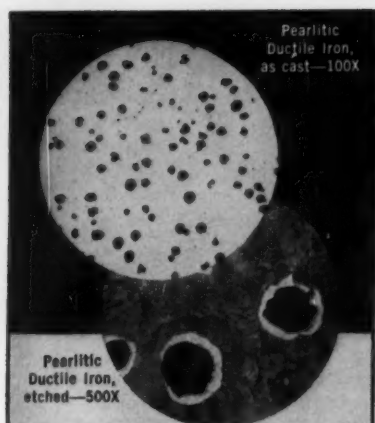
**William M. Ewing, Jr.** . . . 36, assistant to general superintendent at Shennango Furnace Co., Sharon, Pa.

**Frank J. Krebs** . . . 76, retired president, Capital Brass & Aluminum Foundry Co., Chicago. He retired as president in 1957 after 35 years service with the firm.

**Jean-Pierre Menant** . . . 61, engineer of arts and manufacturing, Chief of the Castings Div., Centre Technique Des Industries De La Fonderie, Paris, France.

**J. G. Winget** . . . foundry superintendent, Reda Pump Co., Bartlesville, Okla.

**William K. Sproule** . . . 48, consulting metallurgist, Research & Development Div., International Nickel Co., after a long illness.



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Kawin services perform a vital function—in establishing quality controls; by confirming or supplementing your laboratory findings; by determining causes of material failure; by assisting in development and application of new alloys and techniques to meet specific requirements.

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Circle No. 168, Pages 141-142

## New Metalcasting Equipment and Processes

*What's new in foundry methods and equipment? Summaries are presented below. Circle corresponding number on free postcard, page 141. Mail it to us; we'll do the rest.*

**Conversion chart . . .** includes common factors such as inches to centimeters or watts to H.P. as well as many difficult to locate in reference manuals. Precision Equipment Co.

Circle No. 1, Pages 141-142

**Tooling plastics brochure . . .** outlines typical applications in four pages. May be used for patterns, core boxes or match plates. Furnace Plastics, Inc.

Circle No. 2, Pages 141-142

**Compact vacuum pump . . .** completely portable, has a maximum vacuum of 27 in. Hg and will move up to 1.5 cfm of air with entrained liquids. Frederic B. Stevens, Inc.

Circle No. 3, Pages 141-142

**Permanent molding machine . . .** four-cavity universal automatically-cycled unit, produces pistons up to 2¼ in. in diameter up and exceeding 240 per hour. Molds, cores, and head cores are air or water cooled to speed solidification and rapid cycling. Permanent Mold Die Co.

Circle No. 4, Pages 141-142

**Die casting unit . . .** produces medium size zinc or aluminum castings up to 12½ lb in zinc or 5.8 lb in aluminum. Can be equipped for vacuum die casting. Cleveland Automatic Machine Co.

Circle No. 5, Pages 141-142

**X-ray testing . . .** speeded through self-contained unit which radiographs 2-in. thick steel and handles 1-in. steel in less than one minute. Can be operated remotely from 25 ft by dry cell control. Picker X-Ray Corp.

Circle No. 6, Pages 141-142

**Gray and ductile buyers guide . . .** published by Gray Iron Founders' Society, contains three distinct sets of data. Alphabetical listing contains member foundries with personnel, monthly production, size, type and use of castings, foundry classifications, type of iron produced, and specific facilities. Firm trade names are also

shown. Geographical listing aids in location sources and a buyers guide lists foundries under products manufactured. Gray Iron Founders' Society.

Circle No. 7, Pages 141-142

**MODERN CASTINGS Index . . .** for 1960 facilitates location of important events of the year. American Foundrymen's Society.

Circle No. 8, Pages 141-142

**Castings defects . . .** causes and cures are contained in 8-page brochure. Illustrated with pictures, charts, and graphs. Foseco, Inc.

Circle No. 9, Pages 141-142

**Industrial heating furnace . . .** control systems catalog, 24 pages, includes 50 photographs and diagrams of installations with detailed discussions of the various types of control sub-systems. GPE Controls, Inc.

Circle No. 10, Pages 141-142

**Produce shell cores . . .** stronger, lighter, and thinner with new internal hot air cure attachment. Used with core blower it boosts output by 25 per cent with 30 per cent cut in resin sand used. National Acme Co., Shalco Div.

Circle No. 11, Pages 141-142

**Cut handling time . . .** on heavy lifting jobs with magnets which eliminate rigging heavy loads with chains or hooks. Brochure explains features. Detroit Mold Engineering Co.

Circle No. 12, Pages 141-142

**Makeup air systems . . .** 16 page catalog depicts six basic types of direct gas-fired units and more than 40 models. Designed for automatic, semi-automatic, and manual start-up. Metals Engineering & Mfg. Co.

Circle No. 13, Pages 141-142

**High temperature . . .** high strength alloys used where corrosion resistance and high strength are needed, are featured in new booklet. All materials treated in general booklet with each steel or alloy treated in detail in individual

leaflet. Allegheny Ludlum Steel Corp.

Circle No. 14, Pages 141-142

**Epoxy coating cuts sticking . . .** of granular and abrasive materials to bins, hoppers, and all types of storage and materials handling equipment. Can be brushed, rolled, or sprayed and requires a minimum of drying time. Frederic B. Stevens, Inc.

Circle No. 15, Pages 141-142

**Gouging nozzles . . .** for removing sand incrustations from castings produce greater preheat than previously possible with natural gas or propane. Linde Co., Div. Union Carbide Corp.

Circle No. 16, Pages 141-142

**Electrolytic manganese . . .** 8-page data sheet discusses use of manganese in steel and aluminum, and other non-ferrous metals. Foote Mineral Co.

Circle No. 17, Pages 141-142

**Rubber bearings . . .** solve sand abrasion problems in bearings for Michigan foundry. Three-page data sheet tells how new bearings have provided answers. E. I. Du Pont De Nemours & Co.

Circle No. 18, Pages 141-142

**Non-destructive testing method . . .** cuts magnetic particle inspection time on large castings from days to hours with increased reliability. System employs vector method of overall magnetization in conjunction with fluorescent wet inspecting medium. Magnaflux Corp.

Circle No. 19, Pages 141-142

**Compact swing frame grinder . . .** cuts operator fatigue through balance and has three handle arrangement allowing maneuverability. Accommodates grinding wheels 7 in. in diameter or 10 in. in diameter with 1 in. face by 1 in. bore. Grinding & Polishing Machinery Corp.

Circle No. 20, Pages 141-142

**Hot-handling gloves . . .** protect hands against heat of hot cores or molds and radiant heat of heater plates. Reportedly outlast other standard extra-heavy weight cloth gloves. National Acme Co., Shalco Div.

Circle No. 21, Pages 141-142

**Self-tapping inserts . . .** give speed installation of threads in aluminum and magnesium alloys. Chamfers at both ends facilitates hand

feeding and simplifies automated arrangements. SpeedSerts, Inc.

Circle No. 22, Pages 141-142

**Power tool line . . .** in 96-page catalog covers the entire line. Complete specifications, catalog listings, and descriptions of accessories for all tools are included. Delta Power Tool Div., Rockwell Mfg. Co.

Circle No. 23, Pages 141-142

**Self-curing rubbers . . .** consist of two liquids, simply mixed to form strong, tough, and highly resilient product. They are non-shrinking and thick sections can be poured or cast at one time. Four-page bulletin outlines applications and characteristics. Devcon Corp.

Circle No. 24, Pages 141-142

**Metric conversion calculator . . .** provides conversions instantly from minus 459 F to plus 3000 C and decimal and metric equivalents of parts of an inch are available as are a large number of simple metric-English conversion formulas. Sold individually or in quantities of five or more. Kelm Mfg. Co.

Circle No. 25, Pages 141-142

**New fan bulletins . . .** cover heavy duty draft inducer, roof fan, and centrifugal blowers. Stamford Fan Co.

Circle No. 26, Pages 141-142

**Continuous, automatic vibratory . . .** finishing handles work fed or conveyed. Media are automatically cleaned, screened, and recirculated. Elongated work containers may also be adapted to batch type processing of very long parts. Pangborn Corp.

Circle No. 27, Pages 141-142

**Sliding blast gate . . .** made of heavy gage brass insures smooth and easy operation within gate body made of cast iron, bronze, steel, stainless steel, or aluminum. Schurs Burner & Equipment Co.

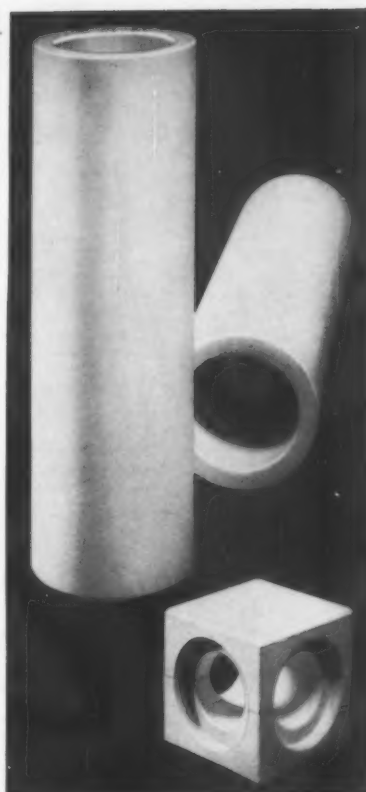
Circle No. 28, Pages 141-142

**No-bake process . . .** applications showing how production is speeded are contained in four-page brochure. Pictures give emphasis to large cores. G. E. Smith, Inc.

Circle No. 29, Pages 141-142

**Physical and mechanical properties . . .** of castings made with T-1 steel composition are covered in four-page brochure. Esco Corp.

Circle No. 30, Pages 141-142



## Louthan gate tiles cut foundry costs

You minimize casting problems, get cleaner castings when you use Louthan refractory gate tiles (elbows and tees to match). They prevent erosion of the gates in steel castings, safely withstand high temperatures, will not react with the molten metal. All popular diameters and lengths can be furnished.



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A UNIT OF **FERRO** CORPORATION

*Refractories Division*

Circle No. 109, Pages 141-142

## SERVO LIFT



Servo Lift used to transfer molds from a conveyor to shakeout. To lift or lower the mold the operator simply takes hold of the operating handle and raises or lowers his hand to the desired level. The mold automatically follows the smooth natural movement of the hand with as much speed and accuracy as needed. Various styles of hooks or grabs can convert the Servo Lift for many applications in a matter of minutes. Power is supplied from any 90 P.S.I. airline.

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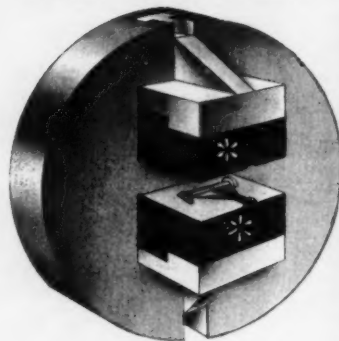
## SERVO LIFT

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Circle No. 178, Pages 141-142

modern castings

## Make Holding Fixtures Quickly / Easily with EPOCAST



- Absorbs Inertia
- Eliminates Tool Chatter
- Compensates For Casting Variance
- Accurate
- Fast
- Protects Parts From Marring
- Inexpensive

\*EPOCAST is an ideal material for making holding fixtures such as the plastic chucking jaws shown here. It casts in three simple steps. Sets tack free in 2 to 4 hours. Ready for use in 24 hours or less. Makes tooling easier. Send now for technical bulletin giving full information on making chucking jaws.

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Circle No. 171, Pages 141-142

## Classified Advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . . 35c per word, 30 words minimum prepaid. Positions Wanted . . . 10c per word, 30 words minimum, prepaid. Box number, care of Modern Castings, counts as 10 words. Display Classified . . . Based on per-column width, per inch . . . 1-time, \$22.00 6-time, \$20.00 per insertion; 12-time, \$18.00 per insertion; prepaid.

### HELP WANTED

#### NON-FERROUS PLANT METALLURGIST

Aggressive southern manufacturer is seeking a Non-Ferrous Plant Metallurgist who is experienced in all phases of the production of quality bronze alloy and aluminum alloy castings. We want a man who will be able to recognize the existence of a problem and come up with the solution for same, one who is energetic and practical and who can act as a consultant to the foundry superintendent and to Management on all problems pertaining to foundry on non-ferrous questions. We would prefer a man under 35 years of age; will offer a salary between \$8000.00 and \$9000.00 per year with opportunity for advancement on the basis of proven worth and top performance. All replies strictly confidential. Address Box I-106 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**FOUNDRY LAYOUT ENGINEER** — Leading foundry equipment manufacturer needs foundry layout engineer. Should have experience in laying out all types of foundry equipment, material handling and material flows. Excellent salary commensurate with ability. Address resume to Box I-106 H, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**FOUNDRY ENGINEER**—Should have considerable and varied experience with equipment, layout, methods and material flows. For interview in Chicago send complete information on education, employment history, personal data and family status. Replies will be held confidential. Address Box I-102 H, MODERN CASTINGS, Wolf and Golf Roads, Des Plaines, Ill.

**GENERAL SUPERVISOR** wanted to head up scrap control program in Indiana gray iron foundry. Send resume and expected salary to: Box 1-104 H. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**CHEMIST**—For Smelting and Refining company to analyze non-ferrous metals and alloys. Modern chemical and spectrographic laboratory. Permanent position. Salary open. Write giving full details on background and ability to: Box 1-103 H. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

#### MAINTENANCE FOREMAN ELECTRICAL

Leading steel foundry in the East will have position available for a man thoroughly qualified to handle a variety of problems in electrical maintenance and new installations. All candidates must have well diversified experience ranging from electronics to high tension work and be fully acquainted with modern maintenance management techniques. He must be able to get maximum productivity from his people. For all this the man of our choice will be paid well, have good employee benefits with lots of challenge and opportunity for the future. Complete resumes should be addressed to Box H-103 H. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

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Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

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#### SALES REPRESENTATIVE

We are interested in securing the services, on a salary plus basis, of an aggressive sales engineer to contact and sell the foundry trade. Must have a metallurgical background or equivalent practical foundry experience. Our company is prominent in its field, presently selling a widely used product to all types of foundries.

Man desired should not be over 40 years of age, preferably 30 to 35, free to travel extensively. Headquarters in a medium size Midwestern town with moving expenses paid.

Send complete resume on education and experience and salary requirements. All inquiries held in strictest confidence. Please reply to Box 1-101 H. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Illinois.

**ASSISTANT SUPERINTENDENT**—Must be able to assume full responsibility and supervision of producing miscellaneous types of small gray iron castings. Job will require full knowledge of cope and drag work, match plate, pouring, sand control and core work. This is an excellent opportunity for the right man between the ages of 35 and 45 for future advancement. Send full resume of past experience and salary requirements to: Personnel Director, Muskegon Piston Ring Company, E. Gardner Street, Sparta, Michigan.

#### FOUNDRY SALES

Must have good foundry experience, selling gray iron castings. Age to 35, some college training. Tulsa area. Nationally represented company.

#### CAREER SPECIALISTS

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**FOR SALE**—One Model 2 1/2 F Simpson Mix-Muller, approximately 40 cu. ft. capacity, complete with dust hood and 60 HP motor. Excellent condition. Used 3 years. Address Box 1-107 S. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

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Simpson #3, U.D., 30 cu. ft.  
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\$500,000; main plant estab. 1948 in Bogota plus 5 branches; employs 70 in 40,000 sq. ft. foundry and warehouse buildings. Market: Colombia, Ecuador, Venezuela; maj. prod.: Cu alloy, Pb, Linotypemetal, Al ingots, R.R. bearings, anodes, bells and specialties; production equipment includes 17 furnaces, capacity 300 T weekly, horiz. and vert. ROTOMET centr. cstg., complete modern machine shop, 8 trucks; 1960 sales \$50,000 monthly gross. Write or cable **DISTRAM**, Apto. Aereo 79-94, Bogota 1, D.E., Colombia.

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Young graduate **METALLURGIST** with four years aluminum foundry experience. Military obligation fulfilled. Desire position with responsibility and potential. Mid-west location. Reply C/O Box 1-111 P. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**CONSULTANT-ENGINEER**—Registered professional Engineer Illinois; 24 years experience Ferrous and Non-Ferrous—physical, analytical and quality control. Able to design and produce aircraft quality castings in green sand, waterless molding sand, permanent mold, die casting, centrifugal casting, CO<sub>2</sub> and plaster investment. Available on long or short term basis. Good profit and labor relations record. Box No. 1-106 P. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**FOUNDRY ENGINEER**—Research—Metallurgist, Ferrous and Non-Ferrous, with experience in quality control, trouble shooting and vendor contacts. Knows sand practice, gating, risering and melting practice. 23 years experience in development of new foundry products and processes. Box 1-110 P. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**SALES ENGINEER AND MANAGER FOUNDRY EQUIPMENT OR SUPPLIES**—24 years Ferrous and Non-Ferrous experience in various casting processes. Last position 10 years as Sales Manager of Foundry Supply company. Box 1-109 P. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

**GRADUATE METALLURGIST**, with supervisory experience carbon, alloy and stainless steels, molding, melting, processing and heat treating, seeks broader horizons. Address: Box 1-105 P. MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

#### REPRESENTATIVE WANTED

**FRENCH FIRM**, manufacturers of an automatic chill moulder for light metals (patented machine) seeks REPRESENTATIVE (Agent) in the United States. Send offers to A.A.M.I. 131 rue du 11 Novembre, NANTERRE, FRANCE.

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## The Editor's Forum . . .



**"Forelady"** . . . yes that's the title of the coreroom boss at Kennedy Valve Mfg. Co. in Elmira, N. Y. Mrs. Elizabeth Van Alstine worked nine years as a coremaker before her promotion to forelady. Since taking over she has cleaned up the shop—after all, good housekeeping comes naturally to women—and increased productivity.

Carl Morken, vice president and works manager, says there isn't a better coreroom supervisor in the country. Besides being good at handling both men and women employees, she can design, redesign, and rig coreboxes as well as any man. Mrs. Van Alstine keeps 10 women and four men busy meeting core needs for brass and bronze valve production. Most cores are blown and hardened by CO<sub>2</sub>. Feminine aptitude for careful conscientious work is reflected in their fine safety record. The day I was there was their 514th day without a lost time accident.

Foundrymen around the country certainly have mixed feelings about the use of women in their shops. You will particularly enjoy reading what our columnist Harry Dietrich had to say about the female invasion on page 25 of our July issue and page 26 in August. Harry does a good job of balancing the good with the bad.

One thing for sure, I've never talked to an investment caster who was not completely sold on feminine aptitudes for all the jobs in the wax department. Perhaps there is not so much difference in male and female worker skills—but "vive la difference"!

**Communication is often difficult** . . . in the ideal confines of a classroom. But nowhere is it strained so close to the point of impossibility as in a foundry. Try to get a message through the din-din-din of all-out production to a foreman moving from one trouble spot to another.

Bud Osterman, general foundry superintendent at International Harvester's Louis-

ville foundry, has solved this difficulty by installing a telautograph sending station in his office. Messages written on the "sender" actuate seven "receivers" located in such strategic spots as melt department, core room, molding floor, cleaning room, maintenance office, pattern shop, and assistant superintendent's office. These receivers write the message on a continuous tape which provides a permanent record undistorted by human frailties in a noisy foundry.

Messages might include such items as pattern changes, next day's molding schedule, piece work prices, time study request, and scrap information. "With it down there in black and white foremen have less difficulty with garbled messages. And I know the orders always get through," says Osterman.

Albion Malleable has a similar set-up operating between the chem lab and melt department. As soon as rapid chemicals are run results are reported instantly on the telautograph. Analyses are read on melt department receiver and necessary metallurgy adjustment made immediately. If interested in more details about this equipment just write me.

**Continuous temperature record** . . . is now kept on metal stream flowing from cupola by an optical pyrometer which can be mounted a hundred feet from cupola. Connected to an electronic recorder it automatically provides a continuous permanent temperature record of metal at cupola spout. It also warns operator when metal is running cold.

Instrument can be turned and sighted on metal stream emanating from any cupola in foundry. This certainly is a big improvement over the days when I used to stand in front of a hot stream of metal dodging sparks while squinting through a peep hole in a portable pyrometer! And besides, you get a continuous permanent record of an important variable that has a big influence on quality.

*Jack H. Schaum*

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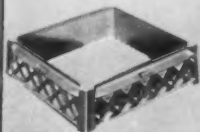


The many inherent advantages offered by HINES "POP-OFF" flasks are augmented by their fabrication in magnesium! The lighter weight will be appreciated by your molders. The extra strength will give you even more accurate production and lower maintenance costs. And, as always, HINES QUALITY will insure a higher percentage of perfect molds.

Here, then, is the ultimate in flask efficiency! If you're planning to improve mold production, be sure to investigate HINES *magnesium* "POP-OFF" flasks. A letter, wire or phone call will bring additional information and prices.

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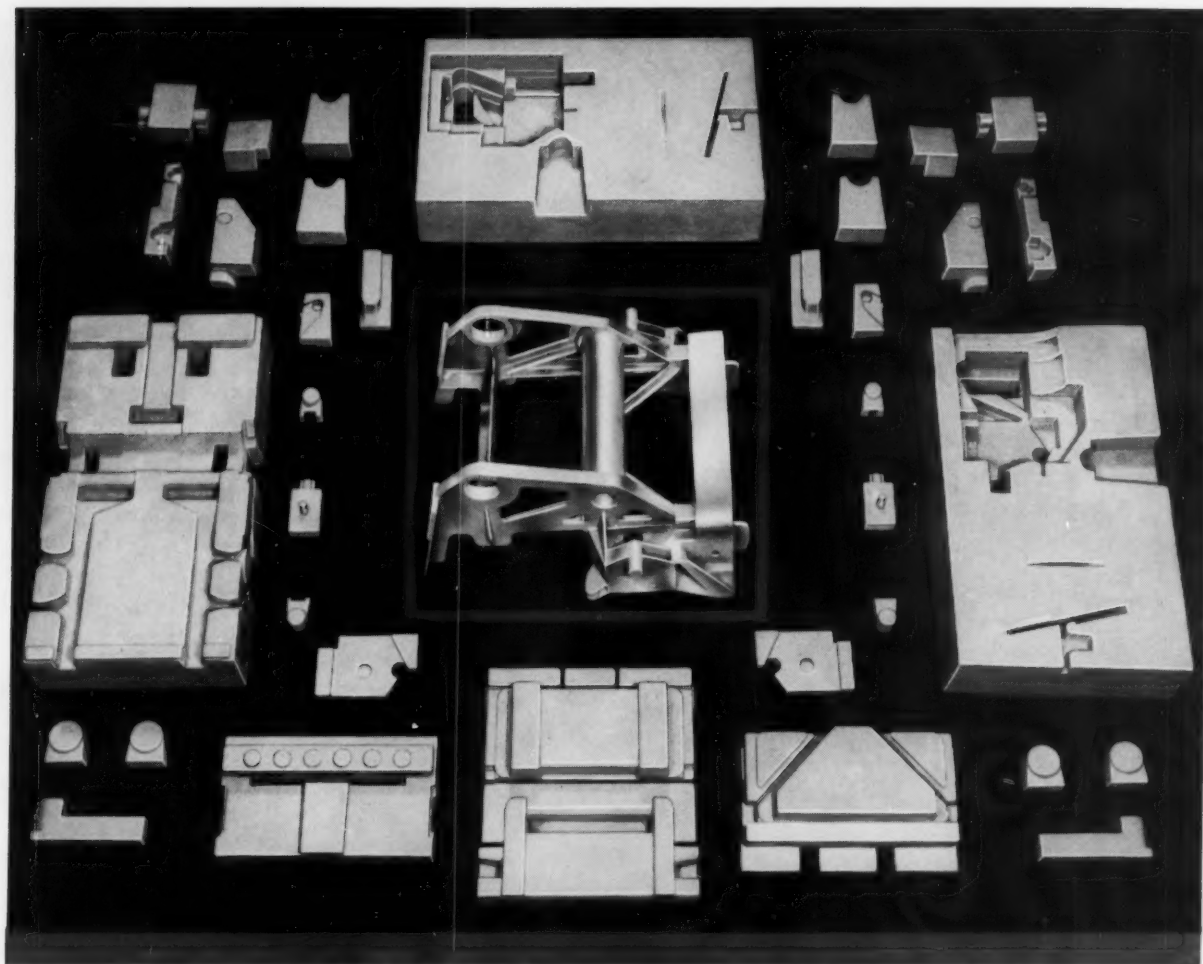
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IF IT'S A "POP-OFF" . . . IT'S HINES . . . IF IT'S HINES . . . IT'S THE BEST

Circle No. 182, Pages 141-142



## How RCI FOUNDREZ CORE BINDER Helped AMERICAN BRAKE SHOE Meet MIL-C-21180A

To produce the strong, dimensionally precise, lightweight casting shown above, the Light Metals Department of American Brake Shoe Company in Mahwah, New Jersey called upon two of the latest advances in metalworking technology... Ductaluminum, a relatively new and stronger aluminum alloy and RCI's FOUNDREZ liquid amino-aldehyde core binder. Used together, they now make it possible for foundries to meet military specifications in castings of this complex nature. ■ Thirty-six individual cores (see illustration) are required to produce this jet canopy casting. And why does American Brake Shoe choose RCI FOUNDREZ for this application? Four factors are involved: 1. RCI's liquid amino-aldehyde core binder provides better binder distribution in the core sand which contributes to exact casting dimensions and keeps surface defects at a minimum. 2. The advantage of dielectric baking, and the high core strength obtained, increases core production and speeds core handling. 3. Excellent core knockout and collapse qualities, at the lower pouring temperatures of aluminum, speed production and reduce the cost of finishing. 4. RCI's reputation for on-time delivery and prompt technical service. ■ If you are pouring metal castings at temperatures below 2700° F, we suggest you investigate the improved core properties offered by RCI's FOUNDREZ liquid amino-aldehyde binder. Reichhold will deliver this unique resin to you from seven convenient shipping points in tank cars, tank trucks or drums. Write today for Technical Bulletin F-2-R for full data on RCI's FOUNDREZ 7600 series.

Creative Chemistry...  
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FOUNDREZ Synthetic Resin Binders  
COROVIT Self-curing Binders  
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